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ON THE MACHINING EXACTNESS OF THE "DUO-PARQUET" ELEMENTS

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SYNOPSIS. Machining in respect to the length and width dimensions of the elements of the duo-parquet in the industry conditions was the focus of the presented studies. The research applied evaluation of the results of the PC program STAT-9000; indexes of qualitative ability of the process were calculated and control cards Shewhart $\overline{x} - s$ were constructed.

KEY WORDS: duo-parquet, dimension exactness, control card

INTRODUCTION

Machining exactness is one of quality features whose dimension exactness is a very important element. It is impossible to produce a series of elements with ideal exactness. The exactness of dimension is expressed by tolerance T, being its allowable interval of variation. To state that the dimension of the produced element is good, its value must be placed in the interval of the tolerance. Assuming that the tolerance interval is forced by standards variation, flowing accordingly to the normal distribution, it is indispensable to assume as mean dimension, the middle tolerance, which not always could be compatible with the nominal dimension. Such compatibility exists only in the case of symmetric tolerance (Zakrzewski and Staniszewska 2002). As a result of action of various systematic and random factors on the processes they undergo changes, which affect the quality level. The base of execution of the quality control of the mentioned parameters in the limits is maintenance in the course of the production variation, which could guarantee the assumed quality level with sufficiently high probability (Iwasiewicz 1999).

At present, automatic quality control in wood processing industry often could not be carried out due to the lack of modern machine tools performing high exactness (Lisičan et al. 2001). Possible is only such the presently accessible control of the process allows stating if and at which level the allowable variation and stability of dimension were executed. The knowledge concerning the exactness of dimension maintenance by the machine tools applied in the process accordingly with the needs of the products is important for a technologist. The method of the examination of exactness of dimension maintenance is also useful for studying other quality features. Therefore, the literature discussing the problem (Czyżewski 1993, PN-ISO3534-2, Zakrzewski and Staniszewska 1995), generally adopts the term "qualitative ability of the process". Besides the qualitative ability of the process, its stability is also important; it means that it guarantees concentration of its values symmetrically in respect to the middle of tolerance area in such a way, that the interval of variability of the controlled value of dimension does not overreach the allowable variation determined for its limits. The main aim of the application of the Shewhart control cards (Matuszewski and Šatanowá 1997, Zakrzewski et al. 2003) is reaching such a state of the process.

The presented study concerns the problem of the statistical control of machining exactness of the two layers flooring-the-so-called "duo-parquet". It is produced mainly for export. The duo-parquet is the product with the finished ready-for-use surface, which does not need additional processing after production. Width and length are the dimensions particularly important in the course of the flooring assembly. Special attention must be paid to their machining exactness during the production of the blocks.

THE SCOPE OF THE STUDY

The aim of the presented study is to describe the performance of the control of the exactness of the length and width dimensions concerning the flooring elements of the duo-parquet with the use of the PC program STAT-9000. It will be obtained by checking the qualitative ability and on the basis of the evaluation of dimensions stability of the produced elements with the use of control cards $\overline{x} - s$.

METHODOLOGICAL ASSUMPTIONS

Measurements of width and length dimensions of the duo-parquet were made in the parquet factory in Biadki. Production of the duo-parquet began in 1999. The product consists of two layers: upper layer face made of oak, beech, birch, ash and maple timber etc.and lower support layer made from residues from the production of mosaic slabs of III quality class of such wood species as oak, pine, birch or ash. The face layer is produced in two versions: lacquered and not lacquered. In the lacquered version the flooring is ready for use. Elements of duo-parquet have sides properly profiled for their joining both in length and width. Dimensions of elements used for measurements were nominally 490 mm long, 70 mm wide and 11 mm thick.

According to the recommendations of DIN-280 standard, the width tolerance is 0.14 mm, and length 0.98 mm.

The way of formation of the cross-section of the duo-parquet is shown on Figure 1, while of the length profile on Figure 2.

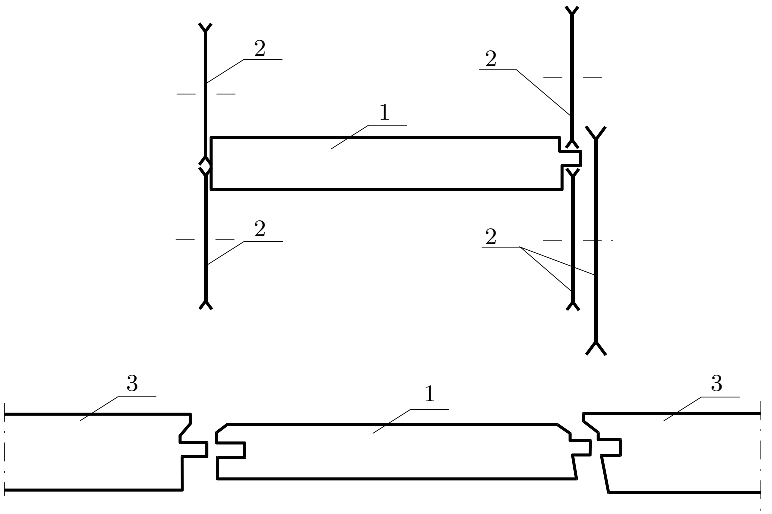


Fig. 1. Method of the formation of cross-section of duo-parquet: 1 – width of element, 2 – saws, 3 – milling cutter
Rys. 1. Sposób kształtowania przekroju poprzecznego duoparkietu: 1 – szerokość elementu, 2 – piły, 3 – frezy

The machining is carried out on the mill-saws produced by Schroeder factory (produced in 1988). The cross profile is made by five circular saws and two profile mills, while the length profile is cut by five circular saws and one profile mill.

For the also measurement of moisture content of elements of duo-parquet resistance, moisture meter type WRD-100 produced by "Tanel" in Gliwice was used. It enables measurements with the accuracy up to ±0.1%. Mean moisture content of ready elements was 7.6%.

The length and width measurements were carried out after final shaping of the flooring elements with the exactness up to ±0.01 mm with the use of electronic caliper produced by VIS in Warszawa. Measurements were made at week intervals and were carried out for five weeks.

For this purpose 25 five element samples were taken from the production line, each ten minutes and then width and length measurements were carried out. Two length measurements at the distance of 10 mm from the wider sides and three width measurements one in the middle and two on sides 50 mm from the front thinner ends were performed on each element. The method of taking measurements is shown on the Figure 3.

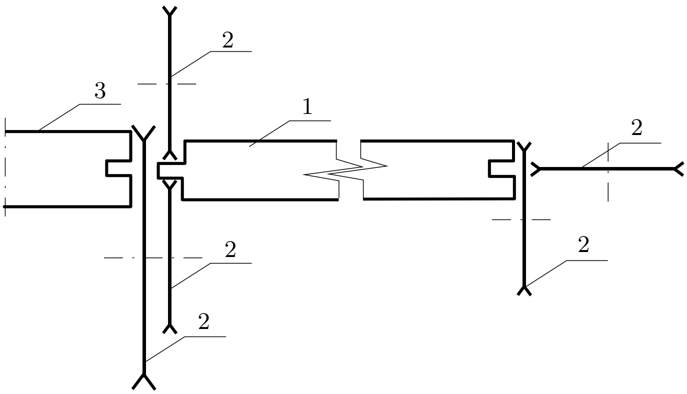


Fig. 2. Method of the formation of the length profile of duo-parquet: 1 – length of the element, 2 – saws, 3 – mill cutter
Rys. 2. Sposób kształtowania przekroju wzdłużnego duoparkietu: 1 – długość elementu, 2 – piły, 3 – frez

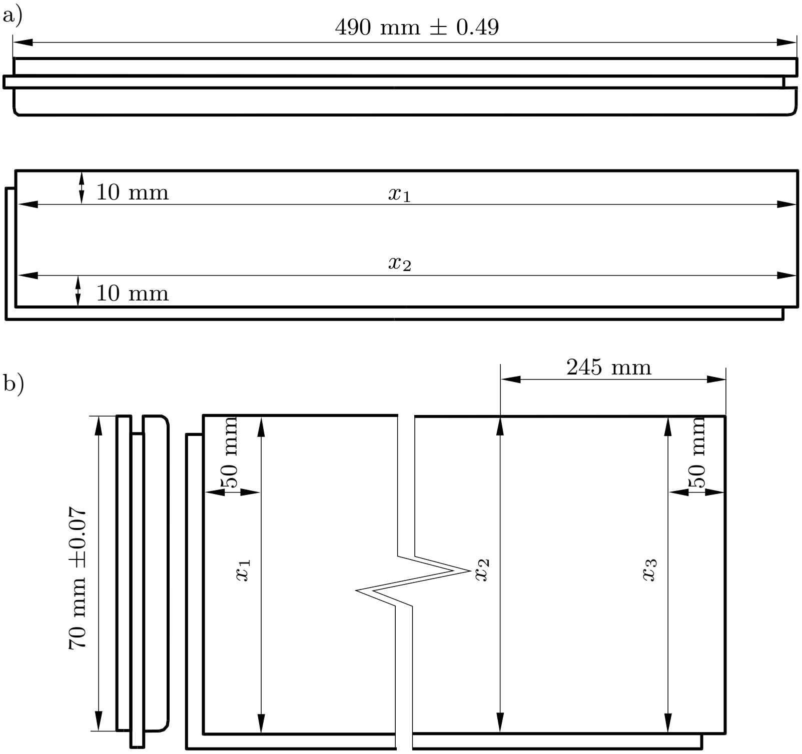


Fig. 3. Method of measurements taken on: a – length of duo-parquet element, b – width
Rys. 3. Sposób dokonania pomiaru na: a – długości elementu duoparkietu, b – szerokości

One length and one width dimensions were calculated in each element from one sample, as arithmetic means from values of proper measurements. So in each week 125 elements were studied from which 625 measurements were taken. In result 250 values were obtained, that is 125 for the length and 125 for the width. The studies were carried out till the moment of replacement of new mill cutters, which were placed only when lacquer exfoliation caused by heating of material due to blunt mill cutters took place.

METHOD OF CALCULATIONS

Calculations of qualitative ability and process stability with the use of statistic method were performed. PC computer, applied for aiding the control of the SKJ processes quality, was utilized as the tool.

The study of qualitative process ability was based on the calculations and observations of the value of two indexes: qualitative process ability c_p and its centering c_{pk}. The value of c_p was calculated from the formula:

$$c_p = \frac{T}{6\sigma} \geqslant 1$$

where: T – dimension tolerance, 6σ – dispersion of dimension (observed).

The form of the process centering index c_{pk} is smaller from two values or

$$c_{pkg} = \left| \frac{B - \overline{\overline{x}}}{3\sigma} \right| \geqslant 1 \quad \text{lub} \quad c_{pkd} = \left| \frac{A - \overline{\overline{x}}}{3\sigma} \right| \geqslant 1$$

where: B and A – upper and lower limit dimension (allowable), $\overline{\overline{x}}$ – arithmetic mean of value from the means from 25 samples consisting of five elements.

To eliminate the rejects, it is necessary to meet $c_{pk} \geqslant 1$. The value of non--centering is also called exactness of dimensional positioning (Staniszewska and Zakrzewski 2002) and it can be written by the formula

$$M_E = \overline{\overline{x}} - N$$

where: N – nominal dimension, $\overline{\overline{x}}$ stabilized arithmetic mean from samples.

The properly adjusted process features maintenance of its lasting stability which means that the values of dimension are symmetrically centered in respect to the middle of the tolerance area in such a way, that the interval of variance of the tested dimension value does not overreach limits of the allowable variation determined for it. Studying of stability is the main aim of application of the Shewhart control cards. The best evaluation of the process of stability is given by two path cards $\overline{x} - s$, very labor consuming at manual calculations, but due to the development of computer technology they replaced the less accurate $\overline{x} - R$ cards (Andrzejewski et al. 1993). On each of two paths of the control cards there is the center line, corresponding to the expected value of the controlled parameter from the sample, and set of control lines-upper GLO and lower DLO. The control lines restrict the allowable limits of the controlled parameter.

The program STAT-9000 applied in the study creates control cards utilizing the stabilization method.

The cards in focus consist of the following parts:

– identification, containing information on the applied method SKJ, the product, the aim of the observation, the nominal value and deviations,

– two paths of control card, being the working part of the card provided for recording control results in form of points determining values of statistical parameters, containing set of lines being limit values of allowable variation of arithmetic mean and mean deviation of the tested numerical value from particular samples,

– informative concerning the magnitude of sample, values of indexes c_p and c_{pk}, and showing if the phenomenon of the middle one third (middle third) occurs.

To ascertain the stability of the process, the values of arithmetic mean $\overline{x}_j$ from five elements sample are calculated according to the formulas:

$$\overline{x}_j = \frac{1}{5}\sum_{i=1}^{5} x_i \quad \text{and} \quad s_j = \sqrt{\frac{1}{5}\sum_{i=1}^{5}(x_i - \overline{x}_j)^2}$$

The arithmetic mean from middle parameters of particular samples is calculated according to the formulas:

$$\overline{\overline{x}} = \frac{1}{25}\sum_{i=1}^{25} x_j \quad \text{and} \quad s = \frac{1}{25}\sum_{i=1}^{25} s_j$$

They are the estimators of parameters μ and σ for the tested set. Mean value from the sample has to be contained within the limits of the upper and lower control lines GLK and DLK. On the path of the $\overline{x}$ card:

$$DLK = \mu - 3\frac{\sigma}{\sqrt{n}} \leqslant \overline{x}_j \leqslant \mu + 3\frac{\sigma}{\sqrt{n}} = GLK$$

on the path of the s card:

$$DLK = 0 \leqslant s_j \leqslant s + 3\frac{\sigma}{\sqrt{2n}} = GLK$$

where: 3 – is multiplication factor of mean deviation of arithmetic mean from samples for the probability of faulty signals 0.27%, μ – mean value awaited in the studied set (for all elements in the batch). As the value μ is not known therefore it is substituted by the mean value $\overline{\overline{x}}$ of means $\overline{x}_j$ from 25 samples with five elements each, alike unknown is substituted by $\sigma = \frac{s}{c_n}$, in which c_n is coefficient dependent upon the sample size (KPN-VIS 1993).

RESULTS AND ANALYSIS

The carried out measurements and statistic calculations were the basis of determination of qualitative ability and stability of dimensions of length and width of duo-parquet. The calculations of qualitative ability and process stability were referred to two various tolerance intervals: one adopted according to the DIN-280 standard and the other one applied in the parquet factory in Biadki. The standard requires to maintain tolerance for length and width for the parquet slabs within ±0.1% of their minimal dimension, while the Enterprise applies ±0.1 mm for both dimensions.

For the evaluation of the measurements, the results were used according to the computer program diagrams of position dispersion of results with the given results of indexes of qualitative ability and centering of process c_p and c_{pk}, histograms frequency of dispersion and control cards of Shewhart $\overline{x} - s$ applying the stabilization method.

Due to the extensiveness of the experimental material and limitations of the article size presented here there are only four control cards that is for the dimension of length and width of the best and worst stabilized process. The values of indexes of qualitative ability of the process c_p and centering c_{pk} referred to the requirements of the DIN-280 standard are placed in Table 1.

Table 1. Values of indexes of qualitative ability and centering of the process for various measurement weeks
Tabela 1. Wartości wskaźników zdolności jakościowej i wycentrowania procesu dla różnych tygodni pomiarowych

		Week 1 Tydzień 1	Week 2 Tydzień 2	Week 3 Tydzień 3	Week 4 Tydzień 4	Week 5 Tydzień 5
Length	c_p	9.93	10.82	13.54	18.45	18.45
Długość	c_{pk}	9.37	9.80	13.33	17.87	17.06
Width	c_p	3.27	4.00	3.00	4.21	4.32
Szerokość	c_{pk}	2.50	3.99	2.51	3.18	2.96

From the data presented in Table 1, it is visible that qualitative ability of the machining of dimension, as well as of length and width of parquet slabs in every week is excellent. Dispersion of dimension of length of process stability is in the best case lower than tolerance by18.45 times (fourth and fifth week) and in the worst case 9.93 times (first week). The centering index is also excellent because it is contained in the limits from 9.37 (first week) to 17.87 (fourth week). Such high values of indexes seem to be the result of great tolerance $T = 0.98$ (according to the DIN-280). In case of dimension of width, as well as values c_p and c_{pk} are visibly lower but also satisfactory. Values of c_p are changing from 3.0 in the third week up to 4.32 in fifth week, while values of c_{pk} from 2.50 in the first week to 3.99 in the second week. The values of process non-centering M_E for particular weeks are positioned in Table 2.

From Table 2 it is apparent that the value of non-centering of the length dimension M_E changes from 0.008 mm in the third week to 0.046 mm in the second week, while width dimension from 0.000 mm in the second week to −0.022 mm in the fifth week of measurements. The average for the length is 0.027 mm, while for the width −0.013 mm.

Table 2. Values for non-centering for various measuring weeks
Tabela 2. Wartości niewycentrowania dla różnych tygodni pomiarowych

M_E [mm]	Week 1 Tydzień 1	Week 2 Tydzień 2	Week 3 Tydzień 3	Week 4 Tydzień 4	Week 5 Tydzień 5
Length Długość	0.027	0.046	0.008	0.015	0.037
Width Szerokość	−0.017	0.000	−0.011	−0.017	−0.022

Table 3. Values of indexes of qualitative ability and process centering for various measuring weeks
Tabela 3. Wartości wskaźników zdolności jakościowej i wycentrowania procesu dla różnych tygodni pomiarowych

		Week 1 Tydzień 1	Week 2 Tydzień 2	Week 3 Tydzień 3	Week 4 Tydzień 4	Week 5 Tydzień 5
Length	c_p	2.03	2.21	2.76	3.77	3.76
Długość	c_{pk}	1.67	1.41	2.70	3.56	2.75
Width	c_p	4.81	5.72	4.29	6.01	6.17
Szerokość	c_{pk}	4.72	4.56	3.92	5.83	6.04

The values of indexes of qualitative ability c_p and centering cpk of the process in respect to tolerance applied by the Enterprise are given in Table 3.

From the data contained in Table 3 results, that for the length dimension values c_p and c_{pk} are much smaller than in Table 1, while for the width dimension they are greater. The value c_p for the length contains in the limits from 2.03 (first week) to 3.77 (fourth week), and c_{pk} is contained in the limit of values 1.41 (second week) up to 3.56 (fourth week). The value of c_p for the width is contained in limits from 4.29 (third week) up to 6.17 (fifth week), while c_{pk} from 3.92 (third week) even up to 6.04 (fifth week).

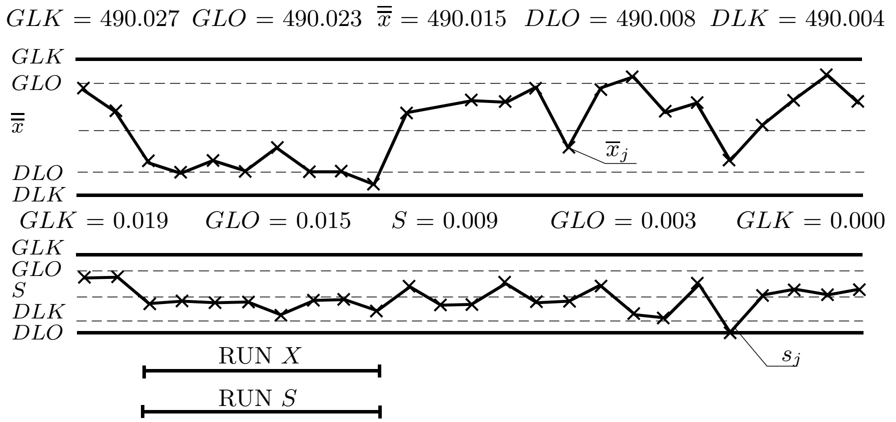
The value of non-centering M_E of the process for particular weeks is presented in Table 4.

Table 4. Values of non-centering for various measuring weeks
Tabela 4. Wartości niewycentrowania dla różnych tygodni pomiarowych

M_E [mm]	Week 1 Tydzień 1	Week 2 Tydzień 2	Week 3 Tydzień 3	Week 4 Tydzień 4	Week 5 Tydzień 5
Length Długość	0.017	0.036	−0.002	0.005	0.027
Width Szerokość	0.003	0.020	0.009	0.003	0.002

From Table 4 it results, that the value of non-centering of length dimension M_E changes from −0.002 mm (third week) up to 0.036 (second week), while for width dimension from 0.003 mm (first and fourth week) up to 0.020 (second week). The average for the length is 0.017 mm while for the width 0.007 mm.

Control card of the process **Karta kontroli procesu** $\overline{x} - s$			
Product Produkt	Duo-parquet Duoparkiet	Length Długość	490
Operation Operacja	Rebate length Pomiar długości	Upper deviation Odchyłka górna	0.49
Feature Cecha	Length Długość	Lower deviation Odchyłka dolna	−0.49

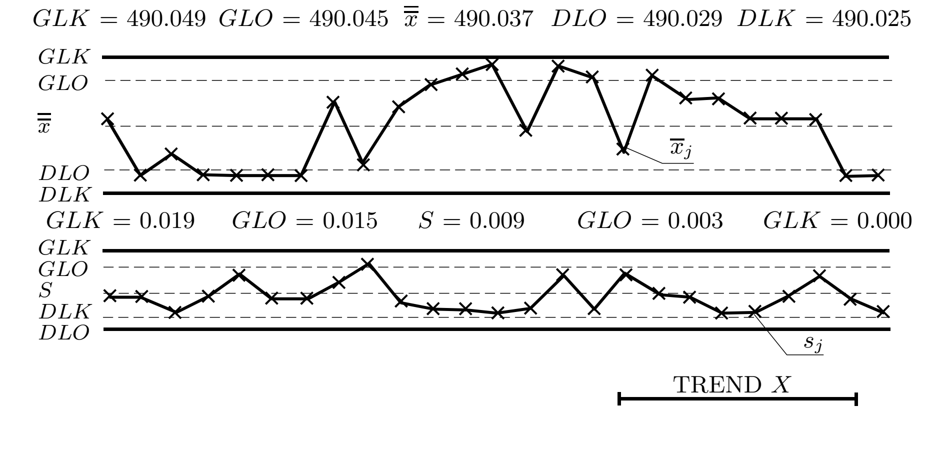


Magnitude of sample Wielkość próbki	5	c_p 18.45 c_{pk} 17.87	Middle third Środkowa jedna trzecia	NO NIE

Fig. 4 Control card of the length dimension in fourth week of measurements
Rys. 4. Karta kontrolna wymiaru długości w czwartym tygodniu pomiarów

On Figures 4 and 5 diagrams of control cards $\overline{x} - s$ made for length dimension for the best and worst stabilized process are illustrated. The best stabilized process was in the fourth measurement week (Fig. 4), while worst in the fifth (Fig. 5). Central lines $\overline{\overline{x}}$ and s and warning lines GLO and DLO are shown in dotted lines and control lines GLK and DLK by continuous lines. Arithmetic means of particular samples $\overline{x}_j$ and s_j are represented by crosses. On Figure 4 the illustration is for the path of arithmetic mean from particular samples $\overline{x}_j$ difference between position of control upper line GLK and lower DLK that is $490.027 - 490.004 = 0.023$ mm, and for path s_j $GLK - DLK = 0.019$ mm while on Figure 5 the range of stability on path $\overline{x}_j$ is $GLK - DLK = 490.049 - 490.025 = 0.024$ mm and on path s_j $GLK - DLK = 0.019$ mm. On Figure 4 (the best stability) random disturbances showing the adjustment of the process did not occur. None of the 25 samples gives the signal of crossing the control line by a single sample both on path $\overline{x}_j$ and s_j; the parameters of two neighboring samples did not cross signal lines either. There occurs a symptom of run type, which means that for seven next samples (that is from third to tenth) values for both statistic parameters $\overline{x}_j$ and s_j are below central lines $\overline{\overline{x}}$ and s. That means that there occurs a momentary systematic dis-

Control card of the process **Karta kontroli procesu** $\overline{x} - s$			
Product Produkt	Duo-parquet Duoparkiet	Length Długość	490
Operation Operacja	Rebate length Pomiar długości	Upper deviation Odchyłka górna	0.49
Feature Cecha	Length Długość	Lower deviation Odchyłka dolna	−0.49



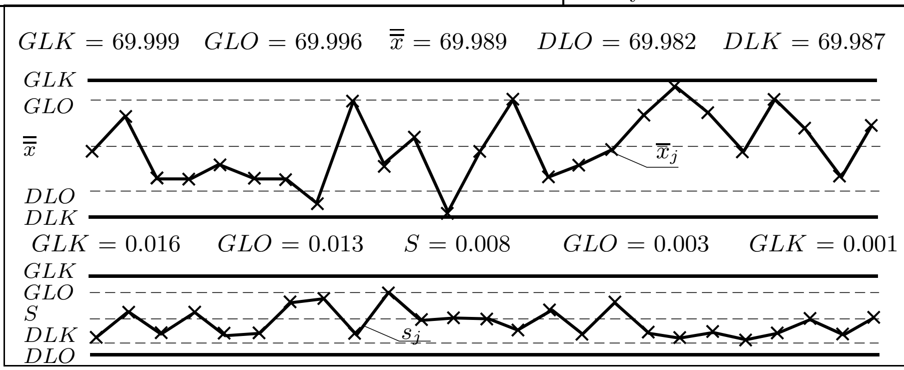
Magnitude of sample Wielkość próbki	5	c_p 18.45 c_{pk} 17.06	Middle third NO Środkowa jedna trzecia NIE

Fig. 5. Control card of the length dimension in the fifth week of measurements
Rys. 5. Karta kontrolna wymiaru długości w piątym tygodniu pomiarów

turbance in the process. Although on Figure 5 (worst stability) no random signals occur on crossing control lines both on path $\overline{x}_j$ and s_j, but signals based on crossing by next samples (4-7, 12-13, 15-16, 24-25) of warning lines are observed. For the parameter $\overline{x}_j$, for samples from 18-24, additionally the trend x phenomenon also occurs indicating systematic disturbance in the process. This phenomenon consists in the fact that for the 7 next selected samples value $\overline{x}_j$ is continuously diminishing.

On Figures 6 and 7 are presented control cards $\overline{x} - s$ made for the width dimension of the best and worst stabilized process. The best stabilized process was in the third measuring week (Fig. 6), while the worst in the first (Fig. 7) for the path of arithmetic mean from particular samples $\overline{x}_j$. In the third week the range of stability of dimension is on path $\overline{x}_j$ the difference $GLK - DLK = 69.999 - 69.978 = 0.021$ mm, while on path s_j $GLK - DLK = 0.015$ mm. However, in the first week on path $\overline{x}_j$ the range of stability $GLK - DLK = 69.991 - 69.973 = 0.018$ mm, while on path s_j $GLK - DLK = 0.014$ mm. On Figure 6 (the best stability) random disturbances testifying the adjustment of the process do not occur. None of 25 samples gives the signal of crossing the control line both on

Control card of the process Karta kontroli procesu $\overline{x} - s$			
Product Produkt	Duo-parquet Duoparkiet	Width Szerokość	70
Operation Operacja	Rebate length Pomiar długości	Upper deviation Odchyłka górna	0.07
Feature Cecha	Width Szerokość	Lower deviation Odchyłka dolna	−0.07



Magnitude of sample Wielkość próbki	5	c_p 3.00 c_{pk} 2.51	Middle third Środkowa jedna trzecia	NO NIE

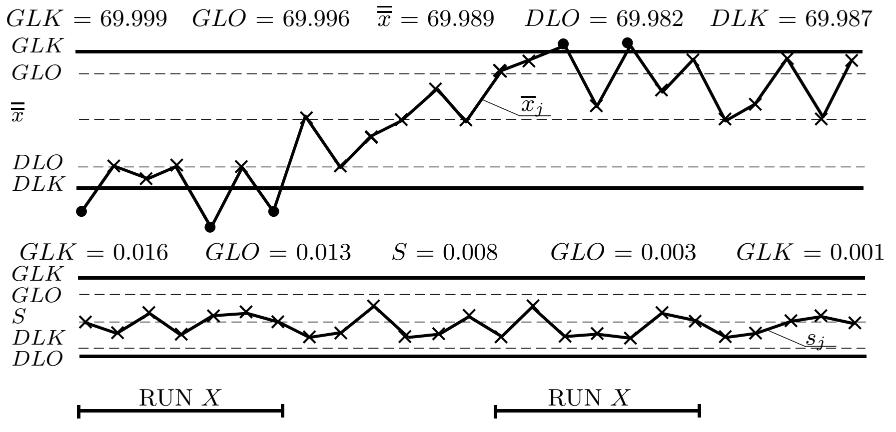
Fig. 6. Control card of the width dimension in the third week of measurements
Rys. 6. Karta kontrolna wymiaru szerokości w trzecim tygodniu pomiarów

path and s_j by a single sample, and parameters of two adjacent samples do not cross values of warning lines. Did not also occur No systematic disturbances of the trend or run, or middle third type occurred either. On Figure 7 (worst stability) random and systematic disturbances occur only on path x_j. On path s_j there is lack of any disturbances. Samples 1, 5 and 7 give arithmetic means $\overline{x}_j$ lying below the lower control line while samples 16 and 18 above the upper control line; it denotes random signals of readjustment. The points are denoted by darkened circles. Besides there occurs two the phenomenon of run type x (samples 1-7, and 14-20) occurs twice testifying systematic disturbances taking place in the process.

The adjustment of the process occurring on paths $\overline{x}_j$ for the worst situation and for the dimension of length and width can be noticed from the observations of Figures 4-7, while there is a lack of random signals the process of the adjustment on path s_j.

The signal testifying systematic disturbances of the process occurs on path s_j; only on Figure as run s, and for path $\overline{x}_j$ occur the phenomena of trend type x on Figure 5 and run x on Figures 4 and 7 occur. The phenomena of middle third type occur on none of the cards.

Control card of the process Karta kontroli procesu $\overline{x} - s$			
Product Produkt	Duo-parquet Duoparkiet	Width Szerokość	70
Operation Operacja	Rebate length Pomiar długości	Upper deviation Odchyłka górna	0.07
Feature Cecha	Width Szerokość	Lower deviation Odchyłka dolna	−0.07



Magnitude of sample Wielkość próbki	5	c_p 3.00 c_{pk} 2.51	Middle third Środkowa jedna trzecia	NO NIE

Fig. 7. Control card of the width dimension in the first week of measurements
Rys. 7. Karta kontrolna wymiaru szerokości w pierwszym tygodniu pomiarów

CONCLUSIONS

1. On the basis of observations of the index of qualitative ability of pf process, the production process c_{pk} is evaluated as qualitatively able both in respect to the DIN-280 Standard, and to the standards observed in parquet factory in Biadki.

2. For the length the dimension signals of de-adjustment of the process arose from the fact, that some values of arithmetic means from samples overreached the warning lines, and run and trend phenomena occurred.

3. For the width dimension signals of de-adjustment of the process occurred since the some values of arithmetic means from samples overreached the control lines, and run and trend phenomena occurred.

4. The magnitude of blunting of the tool edges in the five-week period influenced the disturbance of the results to an insignificant extent.

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BADANIE DOKŁADNOŚCI WYKONANIA ELEMENTÓW DUOPARKIETU

Streszczenie

Przedmiotem badań była kontrola dokładności wykonania wymiarów długości i szerokości elementów duoparkietu przeprowadzona w warunkach przemysłowych. Pomiary przeprowadzono w fabryce parkietów w Biadkach.

Wyniki badań opracowano z zastosowaniem programu komputerowego STAT-9000 służącego 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 $\overline{x} - s$ w odniesieniu do wymagań normy DIN-280 oraz do norm przestrzeganych w Zakładzie.

Na podstawie obserwacji wartości wskaźników c_p i c_{pk} proces oceniono jako zdolny jakościowo, aczkolwiek sporadycznie wystąpiły sygnały świadczące o jego rozregulowaniu (niestabilności).

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