

AN ATTEMPT OF CLEARANCES COMPENSATION IN ANGLE JOINTS OF WINDOWS IN SERIAL PRODUCTION

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Tested was accuracy of angle joints in windows in the industrial condition with the use of SPC method. Elaborated and applied was also in production of windows the method of control of mean clearance of mortices and tenons of joints. Control was achieved with the use of exchangeable washers under mills and written in this purpose computer programme.

Key words: window sill, fitting, angle joint, fork, mortice, tenon

INTRODUCTION

Article is devoted to problems of accuracy of dimensions of angle joints in the system of windows "Eurofalz" DJ-68 produced accordingly to Technical Approval JTB AT-15-2/948/98. Till to this time published articles (Staniszewska et al. 1994, 1996, 1998) from the range of dimensional accuracy of machining joints pertained only single mortices and tenons applied in furniture industry for production of frame furniture. However in joinery plants are used mainly double tenon-fork joints for assembly of sills and window and door frames.

Till to this time considered single tenons of chairs were produced on the envelope tenoning machines, and co-operating with them mortices on the drill-milling machines, while double tenon-mortice joints are produced mainly (in mass and multi-series production) on two sides multiple spindle tenoning machines.

Diversity of presented in previous articles on single joints and considered in this work double joints results not only from technological differences of their production, but above all from the character of co-operation of elements of joints in both cases. Single mortices and tenons could be tolerated obtaining one clearance, while forks of an-

gle joint are creating stiff system giving four clearances five co-operating surfaces. It has been experimentally verified (Rybski 1976, Bieliński and Korzeniowski 1979, Bieliński and Smardzewski 1987), that exactness of make of joints has considerable effect on their strength in course of product service. The lack in till to this time literature of elaboration's solving problem of inspection and control with the mean clearance of angle joints, and also existing in industry the need of its maintenance, caused that author elaborated methods of inspection and control with their dimensional exactness, and execution of verification in industrial conditions on the window produced accordingly to the system "Eurofalz" DJ-68.

METHOD OF CONTROLLING OF MACHINING ACCURACY OF ANGLE JOINTS

There, where on the given magnitude has influence many factors, and establishing effect of each one separately is very difficult, we use statistical calculations. Observed in the tests feature could have various values in dependence upon that what element of given population is studied. Therefore we say that the given magnitude is variable. Variability could have systematic course or at random. Systematic variability could be better controlled and corrected, than the random one. Therefore it is very difficult to establish theoretically effect of all factors on the value of studied feature so, that to forecast effect. Therefore it is the best to determine practically joint effect of factors on the value of feature (exactness of machining), that is in results of statistic study.

In case of tenon-mortice joint, the tested variable feature is clearance occurring between mortice and tenon. This clearance changes in limits from minimum value L_{\min} , through mean L_{sr} till to maximum value L_{\max} (Jezierski 1983). This interval of variability of clearances is determined by symbol T_{pr} for observed fitting (index r) or T_{pz} (fitting tolerance – index z) for allowable variability. The inspection of the exactness of production of the series of elements provided for matching is based on comparison of T_{pr} and T_{pz} values, by calculation of indexes of qualitative c_p ability, and on centring of the process c_{pk} (PN-ISO 1994 Standard).

$$c_p = \frac{T_{pz}}{T_{pr}} \geq 1$$

$$c_{pk} = 2 \cdot \left| \frac{L_{z\max} - L_{r\bar{sr}}}{T_{pr}} \right| \geq 1 \quad \text{lub} \quad c_{pk} = 2 \cdot \left| \frac{L_{r\bar{sr}} - L_{z\min}}{T_{pr}} \right| \geq 1$$

where: $L_{z\max}$, $L_{z\min}$ – clearances maximum and minimum of fitting,
 $L_{r\bar{sr}}$ – mean clearance (observed).

For the inspection and control of exactness of joints production was used elaborated and presented in article (Zakrzewski and Staniszewska 1997/98) method of controlling of the mean clearance. This method elaborated for single joints of mortices and tenons (in chairs) has been modified, because considered window joint has co-operating simultaneously four mortices and four tenons. Angle joints were made on double mortiser produced by the firm Celaschi with two sets for six mills each. One set is used for mortising horizontal sills and second one for vertical (Fig. 1 and 2). Correction of shape of the joints of the blunt tool was made till to this time by the steel washes 5 being between mills 2. Measurement was made with accuracy ± 0.02 mm. Adjustment of the tool was made then, when the observed dimension of tenons and mortices differed from required at least on value ± 0.1 mm. This was caused by that the plant have had not thinner distance washers than 0.1 mm, what practically enabled exact adjustment of mills. During four hour work, tool becomes blunted, what results in change of dimensions of fitted elements. Such changes are so small, that at the lack of thin washers (with thickness below 0.1 mm) there is no possibility of proper their correction. Applying by the factory of the washers for rough correction of the effect of blunting of tool on the shape of milled fork, contributed to invention to apply of such washers for controlling of the mean clearance of mortices and tenons what increases probability of obtaining optimum fittings. However maintenance in course of machining assumed acc. to "Instruction of joining of the sills in angles of wings and balcony doors" COBR of Joinery in Wołomin (1986) of mean clearance $L_{z, sr} = -0.05$ mm caused the need to use washers in steps 0.01 mm.

For controlling of mean clearance were used washers in range of thickness $0.10 \div 0.20$ mm, in steps every 0.01 mm. Said washers were called "matching compensators".

Controlling it is the continuos process based in this case on fitting of tenon thickness and width of forks of vertical sills to the prior produced horizontal sills. In this case are not essential so much values of tenons thickness and width of mortices, but clearances which occur during fitting of horizontal and vertical sills.

The controlling process is divided into two stages. The first it is testing of forks of horizontal sills, because in the process they undergo tenoning process. For measurements are taken three sills produced as the first ones. In each of them were measured with the use of electronic calliper of TESA DIGIT CAL type, with accuracy of ± 0.01 mm in 3 places of two mortices and two tenons of joint elements. In such way were obtained nine thickness dimensions for each two tenons, and nine dimensions of width for each of two mortices. Then calculated were mean values and distribution of width of mortices and thickness of tenon forks. Next sample (three sills) was taken after 45 min, this is the time consumed for production of one transportation palette of horizontal sills.

The second stage that is preparation of the set of mills, to produce first palette of vertical sills, so that when matching with first palette of horizontal sills to obtain assumed mean clearances in all fittings mortice–tenon described conventionally as aA, Bb, cC, Dd. Small letters determine tenon thickness, and big letters width of mortice (Fig. 1 and 2). At that was adapted assumption, that condition of continuation of vertical sills production is that the values of mean clearance $L_{r, sr}$ will be not different from assumed

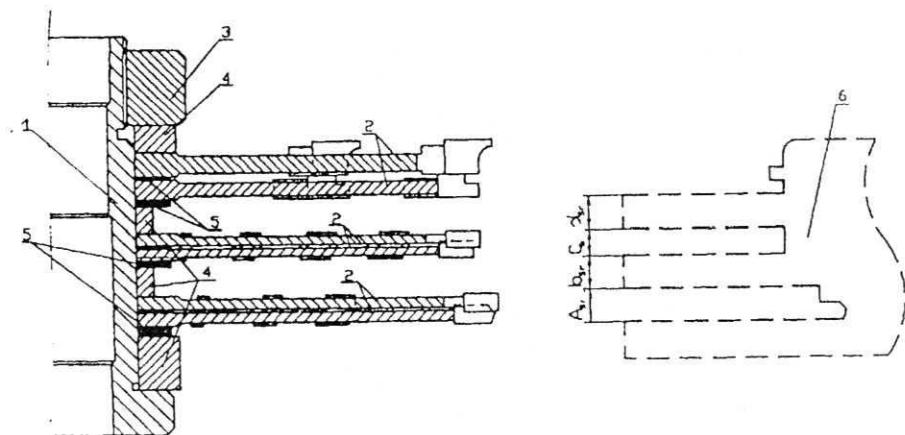


Fig. 1. Set of mills for production of fork of the horizontal still.

1 – spindle, 2 – mill, 3 – tightening nut, 4 – distance sleeve, 5 – adjustment washers, 6 – fork
Rys. 1. Zestaw frezów do wykonania widlicy ramiaka poziomego

1 – wrzeciono, 2 – frez, 3 – nakrętka zaciskowa, 4 – tuleja dystansowa, 5 – podkładki regulujące,
6 – widlica

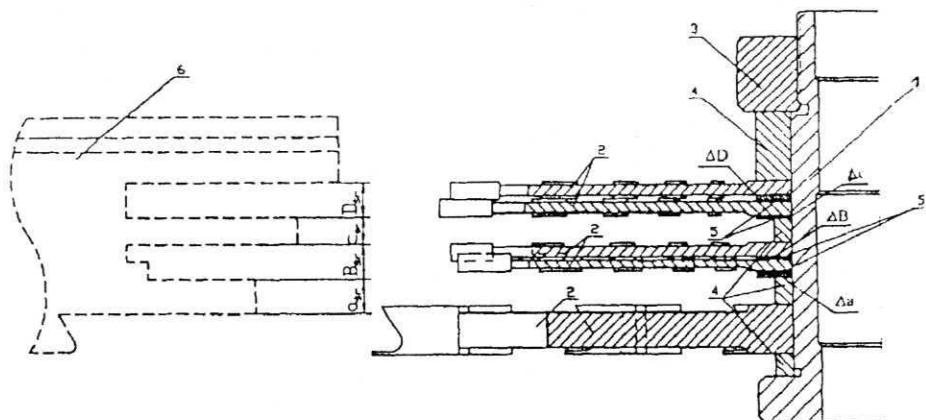


Fig. 2. Set of mills for production of fork of the vertical still.

1 – spindle, 2 – mill, 3 – tightening nut, 4 – distance sleeve, 5 – adjustment washers, 6 – fork
Rys. 2. Zestaw frezów do wykonania widlicy ramiaka pionowego

1 – wrzeciono, 2 – frez, 3 – nakrętka zaciskowa, 4 – tuleja dystansowa, 5 – podkładki regulujące,
6 – widlica

$L_{z, \text{sr}} = -0.05 \text{ mm}$ about not more than 0.02 mm for all four fittings (aA, Bb, cC, Dd). In another case set of mills tenoning vertical sills is corrected by the washers 5 called compensators. **This fitting of tool is repeated till all four fittings obtain assumed mean clearance.** Executed this fittings, tenoning machine works further 45 min till about 250 horizontal sill are made, placed on one transportation trolley. Next part of vertical sills sampled after 45 min is representing sills on the second trolley (provided

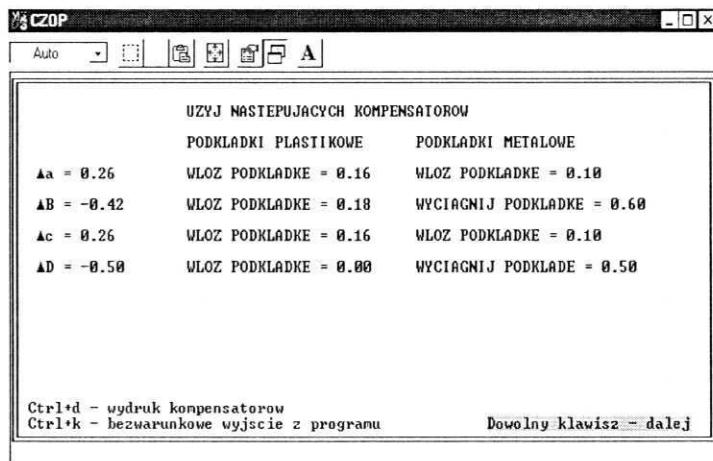


Fig. 3. Last stage of action of the programme "Czop"

Rys. 3. Ostatni etap działania programu "Czop"

for matching with horizontal sills placed on the second trolley. Further proceeding is analogical as for the first sample. Controlling process is repeated five times. At such conduct it is important that the forks of vertical sills from e.g. third trolley were to be matched with horizontal sills also from third trolley.

First stage of controlling it is passive testing of mortices and tenons of horizontal sills, while second stage it is active interference into technological process for obtaining assumed value of mean clearance. This active interference into process needed measurements of mortices and tenons, calculations, and selection of thickness of compensators. To avoid delays in production, was elaborated in Turbo-Pascal programme and applied for controlling of clearances, named "Czop", calculating results of measurements for selector of machining compensators Δa , ΔB , Δc , ΔD (Fig. 2). This programme suggests what changes are to be made in compensation of set of mills in aim to obtain all four mean clearances of joint $L_z sr = -0.05$ mm. On Fig. 3 is shown the last stage of programme action.

In resumption, were carried two series of studies of exactness of fitting of joints. In first it was limited to passive inspection, based on measurements and calculations of exactness of makings of fitting in course of technological process (Staniszewska and Zakrzewski 1988, 1990, 1997). In second series, for verification of theoretical assumptions of controlling of the exactness of joint make, was used active control interfering into technological process.

RESULTS

Results of passive control were graphically elaborated and presented on Fig. 4-7. On the Fig. 8-11 are illustrated results of active control (controlling of the exactness).

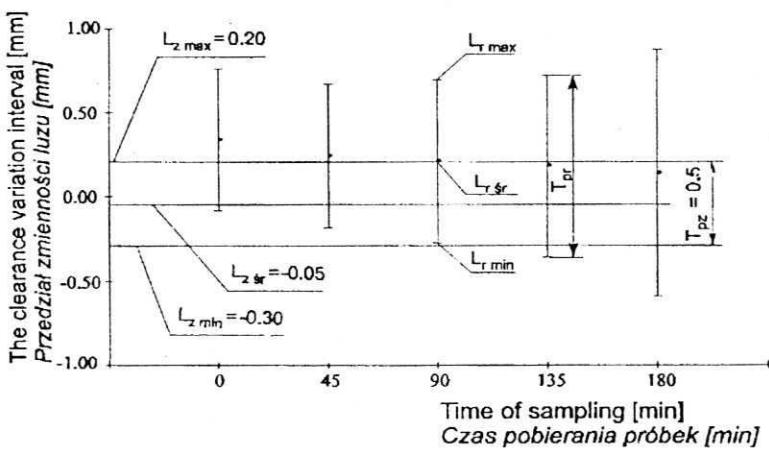


Fig. 4. Results of inspection of the position of distribution of clearance of fitting aA against tolerance area

Rys. 4. Wyniki kontroli położenia rozrzutu luzu pasowania aA względem pola tolerancji

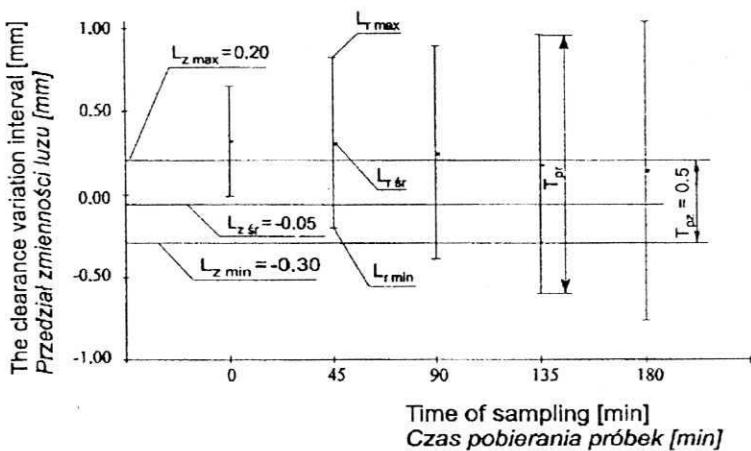


Fig. 5. Results of inspection of the position of distribution of clearance of fitting Bb against tolerance area

Rys. 5. Wyniki kontroli położenia rozrzutu luzu pasowania Bb względem pola tolerancji

c_p	0.60	0.60	0.52	0.46	0.34
c_{pkg}	-	-	-	0.04	0.08
c_{pkd}	1.53	1.30	1.06	0.89	0.61

c_p	0.76	0.49	0.39	0.32	0.28
c_{pkg}	-	-	-	0.03	0.07
c_{pkd}	1.89	1.21	0.86	0.61	0.49

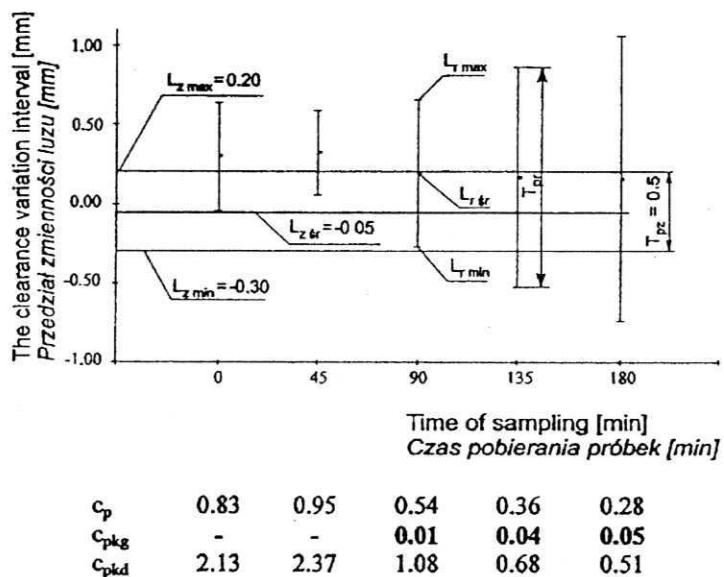


Fig. 6. Results of inspection of the position of distribution of clearance of fitting cC against tolerance area

Rys. 6. Wyniki kontroli położenia rozrzutu luzu pasowania cC względem pola tolerancji

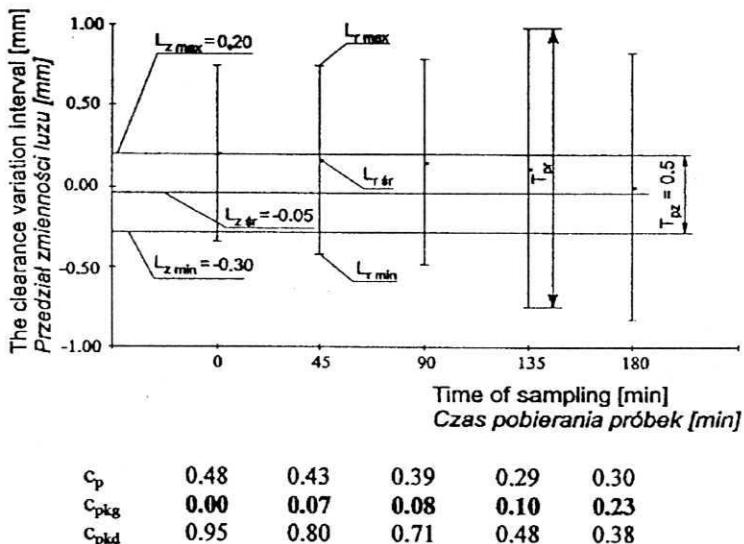


Fig. 7. Results of inspection of the position of distribution of clearance of fitting Dd against tolerance area

Rys. 7. Wyniki kontroli położenia rozrzutu luzu pasowania Dd względem pola tolerancji

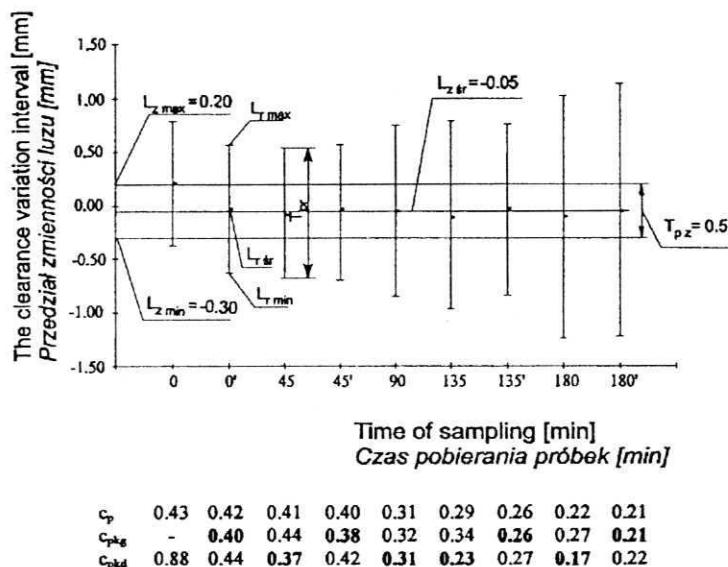


Fig. 8. Results of controlling with mean clearance of fitting aA
Rys. 8. Wyniki sterowania luzem średnim aA

The passive control gives only information on the state of exactness of the product make, while active control improves it (Andrzejewski, Wieczorowski and Żurek 1993, Greber 1997). On figures it is illustrated comparatively positions of clearances T_{pr} dispersion and fitting tolerance T_{pz} . Fitting tolerance was adopted on the base "Instruction of sills joining in the angles" of wings of windows and balcony doors" COBR Joinery in Wołomin (1986).

From the comparison of diagrams Hi-Low on Fig. 4÷7 and 8÷11 distinctly results, that application of active control considerably improves exactness of fitting in comparison with the till to this time state, what has shown rightness of theoretical assumptions. On Fig. 4÷7 mean clearance observed for all fittings and all times of samplings of joints (aA, Bb, cC, Dd) considerably from wanted value $L_{r\text{ sr}} \neq L_{z\text{ sr}} = -0.05$ mm. In every case value of mean clearance $L_{r\text{ sr}}$ is greater than zero, that is $L_{r\text{ sr}} > L_{z\text{ sr}}$. Only for fittings Dd in 180 min of machining observed mean clearance is $L_{r\text{ sr}} = 0.01$ mm, that is differs from assumed only about 0.06 mm. The highest uncentering of clearance is observed at the beginning of machining, then in course of time lapse the value mean clearance diminishes, with exception 45 min of machining in fittings cC, where is observed temporary increase. This diminishing of mean clearance could be explained by consecutive blunting of tools in course of cutting. Abrasion of angles and side cutting surfaces is causing increase of tenons thickness and diminishing of the width of mortices as well in forks of horizontal and vertical sills, what further is causing diminishing of clearances in fittings. This effect of blunting on fitting is double, because gives simultaneous increase of thickness of tenons and diminishing of mortices width in both forks of joint.

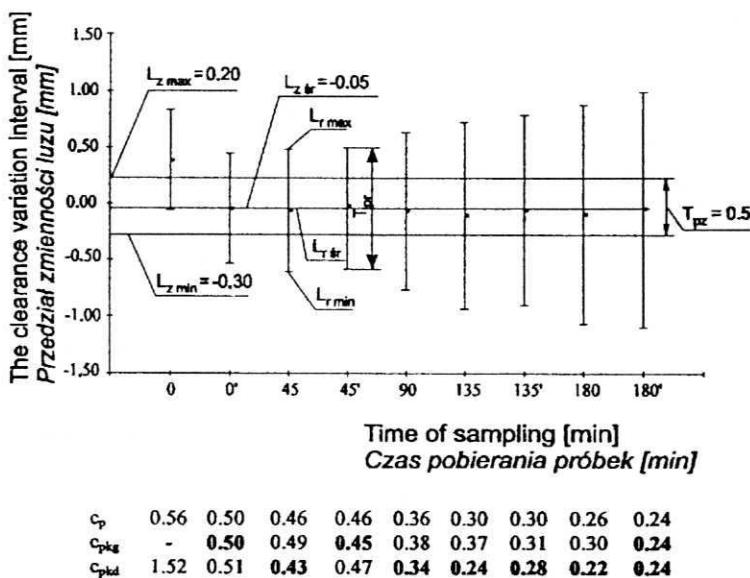


Fig. 9. Results of controlling with mean clearance of fitting Bb
Rys. 9. Wyniki sterowania luzem średnim Bb

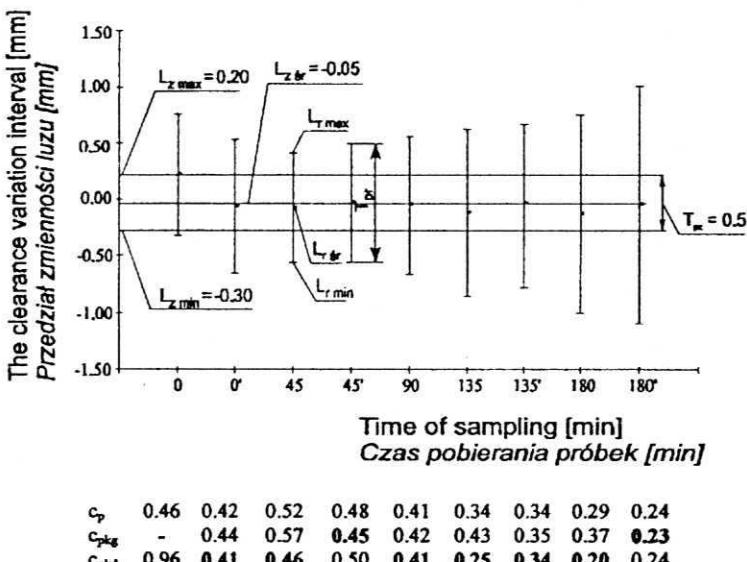


Fig. 10. Results of controlling with mean clearance of fitting cC
Rys. 10. Wyniki sterowania luzem średnim cC

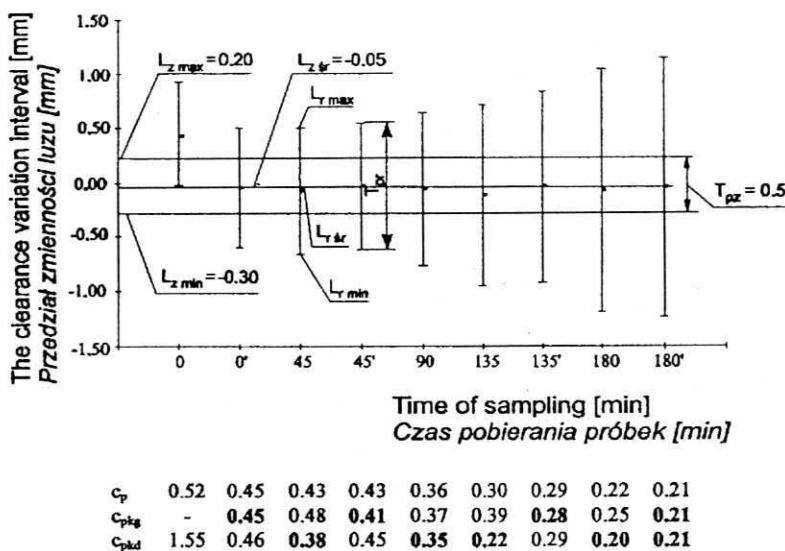


Fig. 11. Results of controlling with mean clearance of fitting Dd
Rys. 11. Wyniki sterowania luzem średnim Dd

On the Fig. 8÷11 can be seen distinct improvement of exactness of fitting. The main advantage which is achieved, that is centring, based on adoption of mean clearance observed to the assumed $L_{r sr} = L_{z sr} \approx -0.05$ mm. However centring is to be made in continuous way. On diagrams is determined time after mean clearance adjustment by the marks ', e.g. 0', 45' etc. In 90 min of machining there was no need for adjustment, therefore was only controlled mean clearance. On those diagrams it can be seen similarly as for passive control, mentioned above tendency for diminishing value of mean clearance of fittings about 0.09 mm during 45 min of machine tool work. The highest uncentering occurs after exchange of mills and starting up machine tool. Therefore adjustment in this time has highest importance.

From the observation of indexes c_p (placed under diagrams) results, that in given conditions of machining fitting is not able in quality, because form the beginning distribution of clearances is higher from tolerance of fitting $T_{rp} > T_{zp}$. This exactness of variability of clearances T_{pr} is so bad, that the index of quality c_p balances from 0.21÷0.95. This disqualifies quality of machining in case of assumption of fitting tolerance on the level $T_{pz} = 0.5$, that is 3 class of exactness acc. BN-81/7140-11/1981.

In average at the beginning of machining, after the placing of sharpened set of tools, distribution of clearances lies in 6 or 7 class of exactness, reaching in fourth hour of machining class 9. Fitting tolerance always certifies quality of fitting of series of elements, but in industrial practice assumed exactness ($T_{pz} = 0.05$ mm) acc. to: "Instruction of joining sills

in angles of wings and balcony doors" COBR of Joinery in Wołomin (1986) is unreachable. In lapse of time of machining this quality ability diminishes (increases distribution of clearances), but centring, in given case, increases probability of obtaining assumed mean clearance $L_{z sr} = -0.05$ mm, deciding on fitting character.

CONCLUSIONS

1. Distribution of clearance overreaches fitting tolerance of studied joints $T_{pr} > T_{pz}$; ($c_p < 1$).
2. As results from carried experiments, prior to inspection and control of mean clearance is stabilisation of range of variability of clearances.
3. Increase of exactness of fitting could be obtained through controlling its mean clearance.
4. Controlling of mean clearance of fitting window sills joints is possible with the use of compensators in form of washers stabilising distance of mills.
5. Carried out in production conditions verification study with the use of machining compensers verified rightness of theoretical assumptions that $\frac{T_{pr}}{2}$ is closer $L_{z sr}$.

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PRÓBA KOMPENSACJI LUZÓW W ZŁĄCZACH NAROŻNYCH OKIEN W PRODUKCJI SERYJNEJ

Streszczenie

Praca dotyczy zagadnienia wymiarowej dokładności obróbki. Celem pracy było opracowanie metody kontroli i sterowania wymiarową dokładnością wykonania pasowania złącz narożnych w systemie okien typu „eurofalz” DJ-68 oraz przeprowadzenie weryfikacji w warunkach przemysłowych. Jako metodę zastosowano SKJ (Statystyczną Kontrolę Jakości). Zakres badań ograniczono do dwóch serii pomiarowych. W pierwszej serii skontrolowano dokładność wykonania 1250 ramiaków pionowych i tyleż poziomych wyprodukowanych łącznie w sześciu godzinach. W drugiej serii prowadzono sterowanie dokładnością wykonania również 1250 ramiaków pionowych i tyleż poziomych wyprodukowanych łącznie w sześciu godzinach. Sterowanie prowadzono z użyciem wymiennych podkładek („kompensatorów”) i napisanego do tego celu programu komputerowego.

Na podstawie przeprowadzonych badań można sformułować następujące wnioski:

- rozrzuł luzu przekracza tolerancje pasowania badanych złącz $T_{pr} > T_{pz}$,
- zwiększenie dokładności pasowania można otrzymać poprzez sterowanie jego luzem średnim,
- sprawą poprzedzającą zagadnienie kontroli i sterowania luzem średnim powinno być ustabilizowanie przedziału zmienności luzów,
- sterowanie luzem średnim pasowania złącz ramiaków okiennych możliwe jest z użyciem kompensatorów w postaci przekładek ustalających odległość frezów,
- przeprowadzone w warunkach produkcyjnych badanie weryfikacyjne z zastosowaniem kompensatorów obróbczych potwierdziło słuszność założeń teoretycznych że $\frac{T_{pr}}{2}$ jest bliżej $L_{z \text{ sr.}}$

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