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Experimental investigation of parts vibratory alignment exciting immovably based part

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1. Introduction

Assembly operations of peg-hole type parts are most common in practice. Automated assembly requires matching of parts' connective surfaces. Therefore part-to-part misalignment errors in assembly position are eliminated, i.e. the parts get aligned. Analyzing assembly of peg-in-hole type parts in most cases the main attention is devoted to parts joining stage. For automated assembly very important is alignment of the parts that commonly determines reliability and duration of assembly operations. Being assembled the parts are aligned in respect of each other using various techniques [1]. The most simple is the alignment by chamfers. Main characteristic of such alignment is that during initial stage of joining the parts must collide by chamfers of connective surfaces and later directional alignment occurs as a result of mutual interaction forces. But the main drawback of this method is relatively small misalignment zone of connective surfaces, when alignment of the parts is still possible. It is possible to perform directional alignment of connective surfaces initially directing connective parts in respect of each other by certain angle. The alignment is predetermined by reaction forces, arising at contact points of connective surfaces. Applying this method it is possible to reduce significantly requirements for parts' preorienting. Sometimes it is possible to increase technological capabilities of assembly mechanisms by mounting resilient elements (compensators) on locating devices. Thus due to resilience of the mentioned elements in locating device axial misalignment and displacement of preoriented parts is compensated.

A model for peg-hole type parts alignment taking into account contact state of the parts and experimental investigation of alignment, when relatively large axial misalignment of the parts being aligned is compensated by maintaining contact between the parts is analyzed in work [2].

Promising are vibratory methods for alignment of the parts being assembled automatically, differing by parts location and excitation techniques. Applying mentioned techniques for alignment of the parts being assembled automatically it is necessary one of the mentioned parts to excite by proper shape and intensity vibrations. Widely applied is automated assembly when parts are located on movable bases and connective surfaces are matched by automated search technique influencing one of the parts by vibratory excitation in two perpendicular directions in a plane perpendicular to the joining direction. But the main drawback of the mentioned method is probabilistic character of the process and therefore insufficient reliability of assembly operation.

More reliable is method of vibratory alignment, when one of the parts to be assembled is subjected to vibratory excitation along the assembly direction [3]. As a result of vibratory excitation the movably based part performs directional motion in matching direction of connective surfaces and so gets aligned in respect of immovably based part. During automated assembly of peg-hole type parts it is possible to base movably and provide excitation both for the peg or for the bushing. This depends on the shape and dimensions of the parts being assembled, construction of the joint, on the method of parts feeding into assembly position and technological requirements.

Vibratory alignment of the parts is successfully applied in different branches of industry, used for assembly of small electronic components. This is especially of present interest at rapidly increasing manufacturing miniaturization [4]. The mentioned assembly method is simple and does not require big investments.

Vibratory alignment of the parts being assembled, analysis of joining forces and joining conditions are theoretically analyzed in research papers [5, 6]. Experimental investigation of parts vibratory alignment under kinematical excitation of movably based peg is analyzed in [7]. It was determined that initially existing errors of part placement in assembly position are compensated due to directional displacement or turn of movably based peg and so conditions for parts alignment and joining are created. This is the main advantage of vibratory alignment.

The main objective of presented paper is experimental analysis of interdependent vibratory alignment of circular and rectangular cross-section parts being assembled automatically, as low frequency vibrations along the direction of connection axis are provided to immovably based bushing. Furthermore, by means of the experiments it is intended to verify investigation results of vibratory motion of movably based body, when immovable base is excited [6]. Experimental results, performed analysis and made conclusions of the investigation are presented.

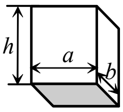
2. Experimental setup and investigation method

For parts alignment experimental investigation an experimental setup was designed and made, which is presented in Fig. 1. One of the parts being assembled, i.e. part *4* with a slot is immovably based on the platform of electromagnetic vibrator *1* (VEB ROBOTRON MESS-ELEKTRONIK OTTO SHON manufactured vibrator with amplifier was used). Peg *3* is attached to resilient element (metallic bellow) *2*. Because of resilient element the peg can move relatively to the bushing and can slightly turn. It is possible to move vertically metallic bellow with the peg attached and so to change pressing force of being aligned parts. A photodiode (not shown in presented scheme) mounted inside lateral face of the bushing was used to fix start/end state of the parts alignment. A mirror is placed in the bottom of bushing's hole to deflect the light beam to the photodiode. To adjust initial pressing force and axial misalignment of the parts indicators were used. An analog signal from photodiode was transformed into digital one by oscilloscope. Signal from oscilloscope is transferred to notebook computer and by means of special software is pictured on a computer screen. Power supply circuit is turned on by a switch, supply and registration circuits are synchronized. Connection of the mentioned elements of experimental setup is shown in structural scheme (Fig. 2).

Alignment experiments have been accomplished with the parts and resilient element of such dimensions and characteristics as given in the Table.

Table

Characteristics of resilient element and being aligned parts

Part	Part dimensions and characteristics,
Cylindrical peg	Material – aluminum; diameter 29.9 mm
Bushing	Material – aluminum; Bushing hole diameter 30.0 mm
Rectangular peg	Material – aluminum; dimensions: *a*=29.9 mm *b*=12.0 mm *h*=16.0 mm 
Slot	Width 30.0 mm
Resilient element (bellow)	Height 38 mm; diameter 28 mm; number of bellow convolutions is 17; axial rigidity 0.04 N/mm

During automated assembly by vibratory technique interdependent position of the parts in assembly position is predetermined both by geometry and by errors of parts fixing in locating devices and positioning errors of feeding devices (e.g. robots). Interdependent position of the parts is characterized by misalignment of their axes or contours of connective surfaces and axial inclination. During assembly with clearance unhindered assembly of the parts is possible only if their total interdependent position error is less than allowable one. For assembly by vibratory technique it is possible not to follow this requirement. Due to vibratory excitation of one part it is possible to compensate considerably higher errors of interdependent misalignment than allowable one and in such a way significantly to reduce the requirements for parts placement accuracy in assembly position.

During assembly the parts get closer and as positioning error is higher than allowable one, contact between the parts exist. During the experiments pre-adjustment of some axial misalignment of the parts or contours of connective surfaces' was made by sidelong displacement of the holder with metallic bellow and the peg attached. It is possible to move this holder downwards and in such manner to press the peg towards the hole by predetermined force. Because of initial pressing force and mobility of the bellow the peg gets tilted relatively to the axis of the bushing by small angle. Tilted circular peg contacts upper edge of the bushing's hole at two points. Rectangular cross-section peg contacts with the edge of the slot. After the oscillator is turned on, alignment process starts as circular (or rectangular) peg attached to the bellow translates towards the hole of the bushing's hole or towards the slot. Alignment duration was measured from the moment of oscillator turn on up to the moment when the peg falls into the hole. The influence of vibrating system and excitation parameters on the process of alignment was investigated.

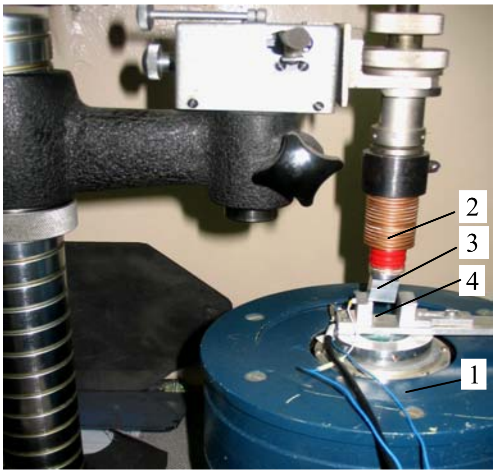


Fig. 1 Experimental setup for parts alignment: *1* – electromagnetic vibrator; *2* – resilient element (metallic bellow); *3* – rectangular (or circular) peg; *4* – part with a slot (in circular parts case – hole bushing)

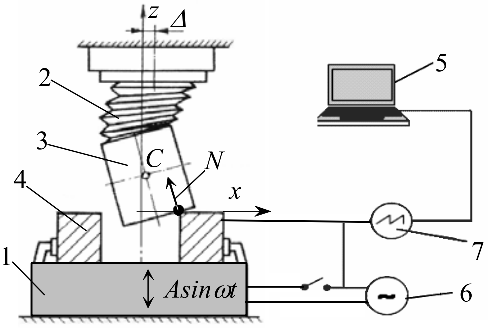


Fig. 2 Structural schema of experimental setup: *1* – electromagnetic vibrator; *2* – resilient element (metallic bellow); *3* – peg; *4* – bushing; *5* – notebook computer; *6* – low frequency oscillator; *7* – oscilloscope

Experiments were performed varying initial pressing of the parts, excitation frequency and amplitude and also initial axial misalignment of the parts. Contact state of the parts, which is predetermined by their interdependent position and intensity of contact forces between the peg and the hole have significant influence on peg-hole type parts alignment process. Alignment of the parts is predetermined by reaction forces at contact points of connective surfaces and by elastic modulus (Young's modulus) of the bellow, arising because of initial preload. Due to mentioned forces and moment and also because of vibratory excitation of the bushing, the peg attached to the bellow, gets oriented in respect to the bushing's hole. Displacement of the peg eliminates axial misalignment and its turn – the tilt. Therefore, the parts get aligned without use of sensors, feedback systems or actuators with feedback systems but only applying dynamical properties of two contacting bodies' under the influence of vibratory excitation.

Vibratory alignment of circular and rectangular cross-section parts without chamfers was investigated. For both cases joining clearance was $\delta = 0.1$ mm. As an efficiency factor for alignment process was chosen the time, within which movably based part translates from initial position to such a position where contours of parts' connective surfaces get matched and the mentioned part falls into the hole.

3. Experimental investigation of parts alignment

During experimental investigation the following parameters were varied:

- initial pressing force F from 0.5N to 2 N;
- excitation amplitude A from 0.5 mm to 1.0 mm;
- excitation frequency f from 50 to 100 Hz;
- axial misalignment Δ of the parts to be assembled varied from 0.5 to 2.5 mm.

Initially the peg is pressed downwards to the bushing by predetermined magnitude force and axial misalignment of connective surfaces is stated. Because of resilient element the peg tilts relatively to the axis of the bushing by certain angle (Fig. 3). Tilt angle depends both on axial misalignment and pressing force. During the experiments tilt angle of the peg was not measured. Pressing force causes normal reaction at contact points of the parts. Due to moment caused by reaction N the peg tilts in relation to the mass center C (Fig. 2). This moment depends on the arm of normal force. Performing alignment of rectangular cross-section peg relatively to the slot, the arm of normal force is $0.5a - \Delta$, where a is peg dimension in the alignment direction; Δ is axial misalignment of connective surfaces. It should be noted, that in this case moment of normal reaction guides the peg towards the axis of the bushing only if misalignment of connective surfaces is less than 0.5 a. When joining of the parts is by cylindrical surfaces and their axes are misaligned, the tilted peg has two-point contact with edge of the bushing's hole (Fig. 3, b). It is possible to calculate coordinates of contact points $x_A = x_B$ as the coordinates of intersection points of bushing's hole circle with radius R_1 and peg's cylindrical surface circle with radius R_2. The circles are defined by the equations

$$\left.\begin{aligned} x^2 + y^2 &= R_1^2 \\ (x - \Delta)^2 + y^2 &= R_2^2 \end{aligned}\right\} \qquad (1)$$

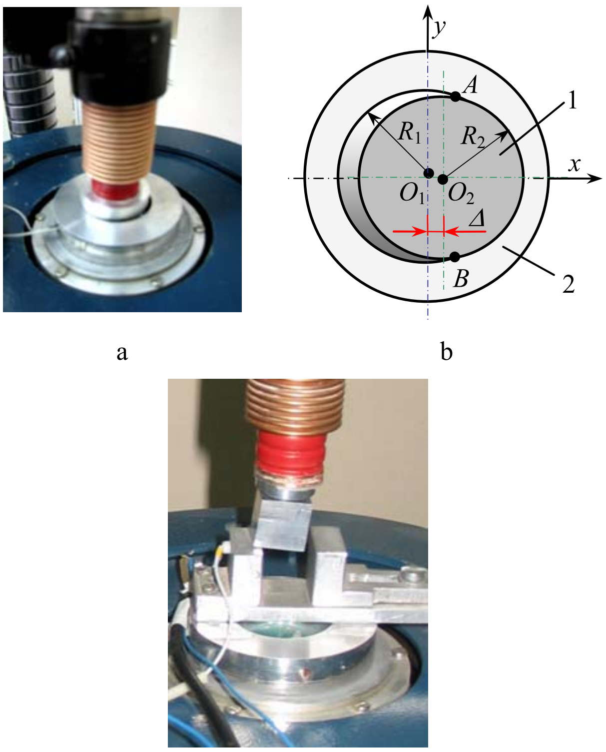
From equations (1) we obtain

$$x_A = x_B = \frac{1}{2}\left(\frac{R_1^2 - R_2^2}{\Delta} + \Delta\right) \qquad (2)$$

When the peg and the hole have equal radii, joining is without clearance and contact points' coordinates are equal $x_A = x_B = \Delta/2$. This means, that contact points are situated to the left from the peg axis. Then under pressing force acting in the direction of joining axis, moment of reaction forces results tilt of the peg relatively to the axis of the bushing's hole. Reaction forces at contact points of the parts are pointed parallel to the joining axis or inclined by relatively small angle in respect of the later. The parts could be in two point contact or surface contact state. Therefore, the process of alignment gets unstable or is not taking place.

Position of contact points in respect to the peg's mass center C depends on joining clearance and axial misalignment of the parts. With the purpose to align the parts successfully it is necessary to ensure both the turn and directional motion of the peg towards the hole of the bushing. Performing alignment of the peg in respect to the bushing's hole, when diameter of the peg is less than that of the hole, i.e. exists a clearance of cylindrical joint, both the parts have no chamfers and are in contact by two points A and B, moment of reaction forces at the points of contact arises and tilts the peg towards the hole if the following condition is satisfied (Fig.3, b)

$$R_1^2 - R_2^2 \geq \Delta^2 \qquad (3)$$



a b

c

Fig. 3 Initial interdependent position of the parts: a – parts of circular cross-section, contacting at two points; b – contact state schema for circular parts: *1* - peg; *2* - bushing; A and B - contact points; R_1, R_2 - radii of bushing hole and circular peg; Δ - axial misalignment of the parts; c – rectangular cross-section parts, edge contact

When both the peg and bushing's hole have equal or nonsignificantly differing diameters, it is necessary to shape a chamfer at least for one of the parts. Then the difference in contacting back surfaces' radii gets more significant and contacting points are located right of the center from the axis of the peg. Therefore, moment of reaction forces causes tilt of the peg towards the axis of the bushing.

Through a gap between surfaces of the parts being aligned, emerging due to axial misalignment, light from the source freely reaches photodiode, which was mounted on lateral surface of bushing's hole (slot). By turning on low frequency oscillator (low frequency signal generator G356/1 was used), axial vibrations along the parts' joining axis are transferred to the bushing. Photodiode via a resistance is connected to Pico ADC 212 oscilloscope and the later is connected with notebook computer. Output signal of the illuminated photodiode is current. Power supply of the vibrator and registering circuit for output signal are turned on simultaneously. Voltage jump pictured on the screen of computer indicates the start of alignment. The peg moves towards the bushing and the parts get aligned.

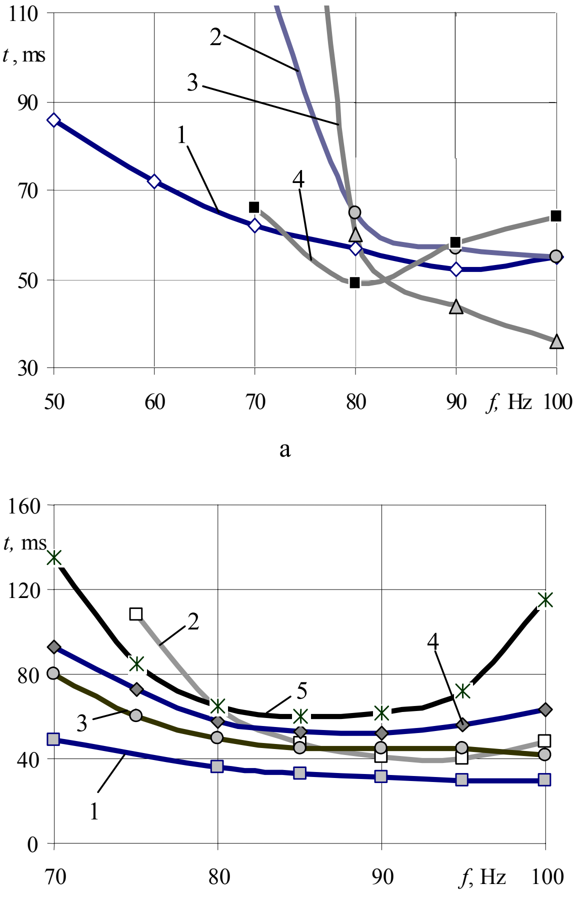
Analog signal obtained by oscilloscope is transferred into a digital signal and by applied software, processed on computer screen. Obtained oscillograms allow us exactly to determine alignment duration of the parts to be assembled automatically.

After connective surfaces are matched, photodiode is shaded by the peg and therefore the light has no possibility to reach the photodiode. Voltage jump of reversed polarity indicates that alignment is finished.

By the obtained experimental results dependencies of alignment duration on excitation frequency (Fig. 4, 5), initial pressing force (Fig. 6), initial axial misalignment (Fig. 7) for the parts of circular and rectangular cross-section were determined. Making mentioned graphical dependencies mean values of alignment duration from 5-7 trials were used.

Excitation frequency has considerable influence on duration and reliability of alignment. It was determined by experiments that in frequency range 50 – 70 Hz under initial pressing force $F = 1.0$ N and connective contours misalignment $\Delta = 1.5;\ 2.0;\ 2.5$ mm circular cross-section parts alignment is not always successful (Fig. 4, a). Under higher values of pressing force ($F = 1.5;\ 2.0$ N) within the mentioned frequency range this tendency still persists, i.e. the process of parts alignment is unstable. For unstable process the alignment duration values, obtained during repeated trials, are substantially different or in some repeated trials alignment does not occur, though conditions of alignment remain the same. As excitation frequency increases (within 80 – 90 Hz frequency range), the process of alignment gets more stable, alignment duration does not exceeds 70 ms. Thus, with the purpose to have reliable process of alignment, it is necessary to tune-up properly the magnitudes of excitation frequency and initial pressing force. Excitation frequency must not be equal to the resonance frequency of vibrating system consisting of metallic bellow and the peg attached. Initial pressing force determines the magnitude of friction force at contact points of the parts. The mentioned force prevents motion of the peg relatively to the bushing. Alignment takes place if horizontal component of normal pressing force along the matching direction is higher than resisting friction force.

Alignment duration dependencies on excitation frequency f for rectangular cross-section parts (Fig. 4, b) show, that alignment of the mentioned cross-section parts, if compared to circular cross-section parts alignment, is more stable process. Within the frequency range from 75 to 95 Hz mentioned process is stable, reliable, having alignment duration not exceeding 80 ms. At higher frequencies (>95 Hz), as axial misalignment of being aligned parts is relatively large (2.5 mm), the alignment duration increases.



a

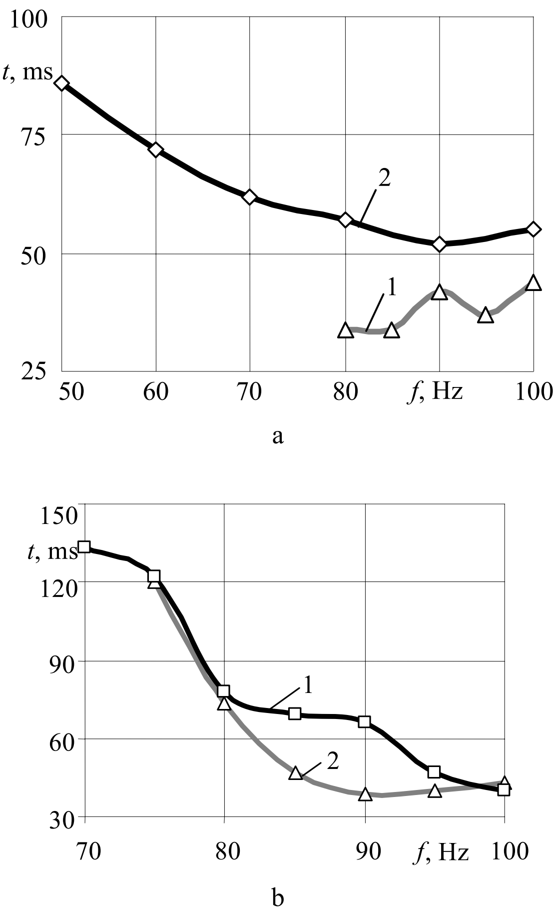
b

Fig. 4 Dependence of parts alignment duration t on excitation frequency f under different axial misalignment Δ, when $A = 1.0$ mm, $F = 1.0$ N : a – for circular cross-section parts: 1- $\Delta = 1.0$ mm; 2 - $\Delta = 1.5$ mm; 3 - $\Delta = 2.0$ mm ; 4 - $\Delta = 2.5$ mm; b – for rectangular cross-section parts: 1 - $\Delta = 0.5$ mm; 2 - $\Delta = 1.0$ mm; 3 - $\Delta = 1.5$ mm ; 4 - $\Delta = 2.0$ mm; 5 - $\Delta = 2.5$ mm

Graphical dependencies of alignment duration versus frequency for different excitation amplitudes (Fig. 5, a, b), show, that circular parts' as well as rectangular parts' alignment duration in frequency range 80 – 100 Hz is relatively short, not exceeding 70 ms. When excitation amplitude is not high enough $(A = 0.5\ \text{mm})$, at a range of lower frequencies (50-80 Hz) the process of cylindrical parts alignment gets unstable or even impossible.

Magnitude of initial pressing force also has an influence on turn angle of the peg and consequently on duration of alignment process. Magnitude of normal force horizontal component that acts on the peg in the axis of matching direction is predetermined by turn angle. As axial misalignment of the parts Δ=1.0 mm, initial pressing force $F = 1$ N and amplitude of vibratory excitation is $A = 1;$ 1.5 mm (Fig. 6, a) alignment process is stable and reliable, without failures of alignment, and duration of the process is relatively small (not exceeding 60 ms). As pressing force increases (F> 1 N) alignment duration changes depending on magnitude of excitation amplitude.

Applying vibratory excitation of insufficient amplitude and under increasing pressing force, alignment duration increases.



a

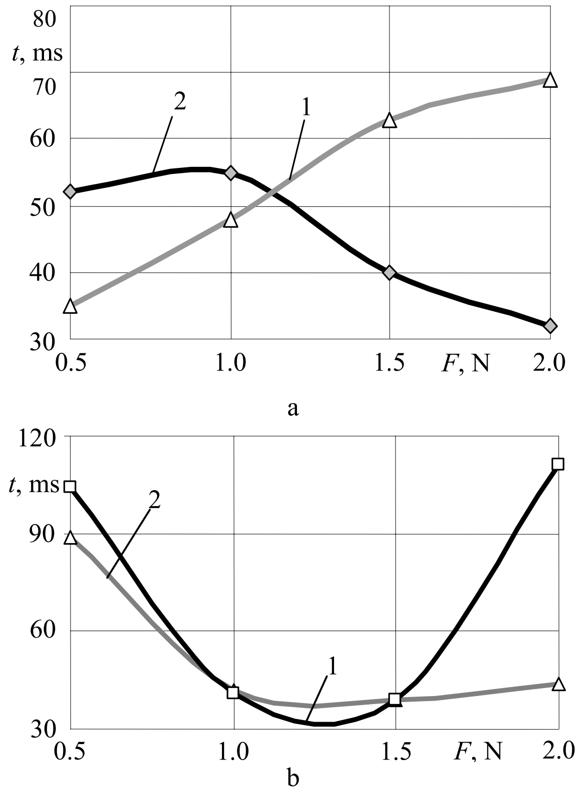
b

Fig. 5 Dependence of parts alignment duration t on excitation frequency f under different excitation amplitudes A, when $F = 1.0$ N, $\Delta = 1.0$ mm: *1* - $A = 0.5$ mm; *2* - $A = 1.0$ mm; a – for circular cross-section parts; b – for rectangular cross-section parts

Dependencies of alignment process duration on initial pressing force F for the parts of circular and rectangular cross-section are different (Fig. 6). However, for both mentioned cases a similar tendency is seen. As magnitude of initial pressing force exceeds 1.5 N, behavior of alignment duration depends on excitation amplitude.

When magnitudes of excitation amplitude and initial pressing force are not properly interdependently matched the process of alignment becomes unstable or is not taking place. To make possible alignment of the parts under higher pressing force applied it is necessary to excite immovably based bushing by higher amplitude vibrations. Axial misalignment has considerable influence on alignment duration (Fig. 7). When axial misalignment Δ is from 1.0 to 2.0 mm, the influence of pressing force F is not strong, the alignment lasts relatively short time – not exceeds 70 ms (Fig.7, a). However, when axial misalignment of the parts is Δ>2.0 mm, the alignment duration significantly increases in such cases, as initial pressing force F exceeds 0.5 N. Similar tendency is also seen in dependencies for rectangular cross-section parts (Fig. 7, b), as initial pressing force is F =2.0 N.

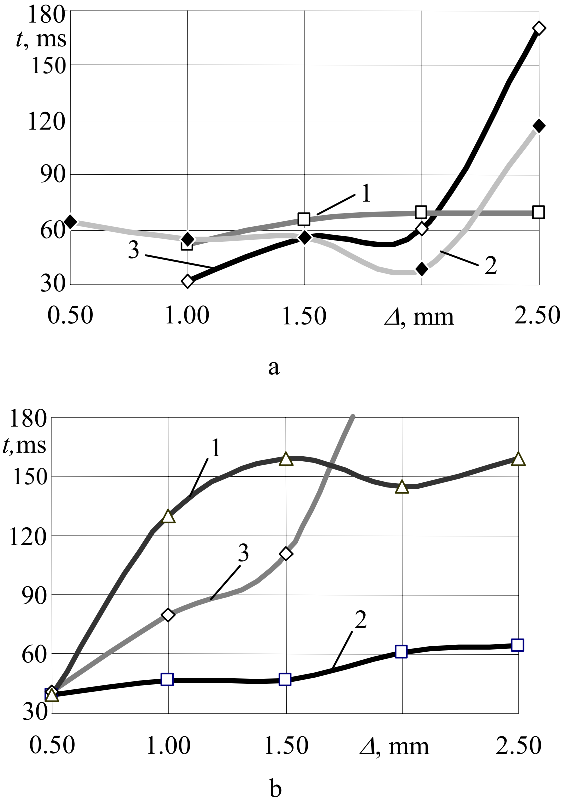
Results of experiments show that alignment process is stable when vibrating system and excitation parameters are properly matched. This is typical both for circular and rectangular cross-section parts alignment.



a

b

Fig. 6 Alignment duration t versus initial pressing force F as $\Delta = 1.0$ mm, $f = 100$ Hz : a – for the parts of circular cross-section; b – for rectangular cross-section parts: *1* - $A = 0.5$ mm; *2* - $A = 1.0$ mm



a

b

Fig. 7 Alignment duration t versus axial misalignment Δ as $A = 1.0$ mm, $f = 80$ Hz: a – for circular parts, as A=1.0 mm; $f = 100$ Hz; b – for rectangular cross-section parts: *1* - F=0.5 N; *2* - F=1.0 N; 3 - F=2.0 N

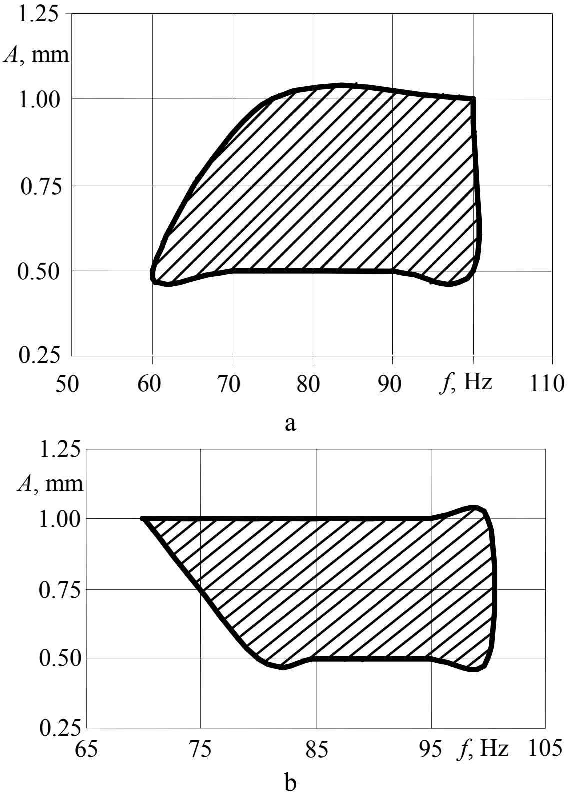


Fig. 8 Area of stable alignment of the parts (hatched) depending both on excitation amplitude *A* and frequency *f* as F=1.5 N, Δ=1.0 mm: a – for the parts of circular cross-section; b – for parts of rectangular cross-section

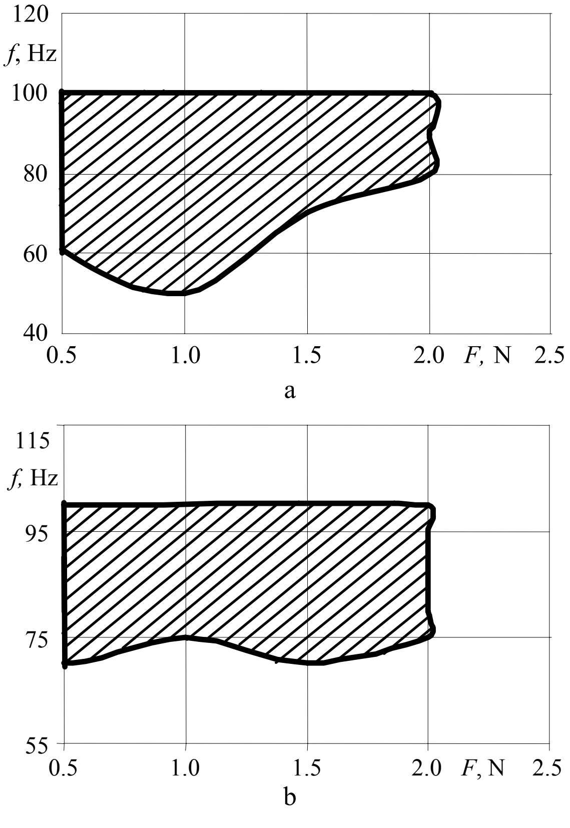


Fig. 9 Area of stable alignment of the parts (hatched) depending on excitation frequency *f* and initial pressing force F as A=1.0mm, Δ=1.0 mm, δ=0.1 mm: a – for the parts of circular cross-section; b – for the parts of rectangular cross-section

Based on experimental data the areas of parameters sets have been defined wherein alignment of the parts to be assembled is stable and reliable (Fig. 8 and 9).

It is possible to make a conclusion that there exists such an interval of excitation frequency wherein the process of alignment goes surely and steady under different magnitudes of excitation amplitude and initial pressing force.

Results of experimental investigation confirmed that excitation of immovably based bushing by predetermined amplitude and frequency vibrations extends technological capabilities of vibratory assembly, since reliable alignment of the parts, having circular and rectangular cross-section, gets possible, even with existing error in assembly position up to several millimeters.

Performed experiments also made possible to verify theoretical investigation results of connective surfaces matching when immovably based part is subjected to excitation [6].

Reliability of alignment process depends on rigidity and dimensions of resilient element, and properly chosen initial pressing force and excitation parameters.

4. Conclusions

1. It was approved by experiments, that it is possible to align parts of cylindrical and rectangular cross-section applying excitation of immovably based part along the joining axis. Thus technological capabilities of vibratory assembly method are expanded.

Reliability of alignment process depends on rigidity of resilient element, initial pressing force, excitation frequency and amplitude.

2. Duration and character of vibratory alignment depends both on excitation frequency and amplitude. When the excitation of higher frequency is applied, the process of alignment is more intensive, therefore the alignment duration is shorter.

Frequency and amplitude of vibrations, at which alignment takes place, are predetermined by mass and rigidity of vibrating system.

3. Applying lower frequency (< 70 Hz) and lower amplitude excitation (0.5 mm) the process of vibratory alignment is unstable, duration of alignment significantly increases and reliability of parts alignment diminishes.

4. Assembly method based on vibratory alignment is suitable for assembly of different shape and dimensions parts. This is simple and inexpensive method, which needs no sensors, feedback systems and control algorithms. Parts get aligned because of dynamical properties of two contacting bodies as a result of one part excitation by predetermined frequency and amplitude vibrations.

References

1. **Bakšys B.**, **Fedaravičius A.** Vibratory systems and mechanisms for automated manipulation.-Kaunas: Technologija.-ISBN 9955-09-841-4, 2005.-373p. (in Lithuanian).
2. **Bruyninckx, H., Dutre, S., De Schutter, J.** Peg-on-hole: a model based solution to peg and hole alignment.-Proc. of the IEEE Int. Conf. on Robotics and Automation, Nagoya, Japan, 21-27 May 1995, v.2, p.1919-1924.

3. **Bakšys B.**, **Pilkauskas K.** Usage of vibrations for automatic assembly. ISMM'97 Int. symposium "Machines and Mechanisms".-Belgrade, Yugoslavia, September 2-5, 1997, p.4-7.
4. **Sudou, M., Takao, H., Sawada, K.; Ishida, M.** Wafer-level integration technology of surface mount devices using automatic parts alignment technology with vibration.-Solid-State Sensors, Actuators and Microsystems, 2005. Digest of Technical Papers. TRANSDUCERS '05. 13th Int. Conf. on Solid-State Sensors, Actuators and Microsystems.-Seoul, Korea, June 5-9 2005, v.2, p.1322-1325.
5. **Bakšys B.**, **Fedaravičius A.**, **Povilionis A.B.** Connection conditions of mobile based parts.-Mechanika. -Kaunas: Technologija, 2002, No5(37), p.19-25.
6. **Bakšys B., Puodžiūnienė N.** Non impact vibratory displacement of a body by plane movement.-Mechanika.-Kaunas: Technologija, 2001, No4(30), p.23-27.
7. **Bakšys B., Baskutienė J., Povilionis A.B.** Experimental investigation of parts vibratory alignment under kinematical excitation.-Mechanika.-Kaunas: Technologija, 2005, No6(56), p.27-32.

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EKSPERIMENTINIS DETALIŲ VIBRACINIO CENTRAVIMO TYRIMAS ŽADINANT NEJUDAMAI BAZUOJAMĄ DETALĘ

Reziumė

Straipsnyje analizuojamas vibracinis automatiškai renkamų detalių centravimas, kai virpesiai suteikiami nejudamai bazuojamai įvorei. Aprašytas eksperimentinis apvalaus ir stačiakampio skerspjūvio detalių centravimo stendas. Pateiktos stačiakampio ir apvalaus skerspjūvio detalių be nuožulnų centravimo trukmės priklausomybės nuo žadinimo parametrų, pradinės prispaudimo jėgos ir renkamų detalių ašių nesutapimo. Sudarytos žadinimo ir sistemos parametrų derinių sritys, kai centravimo procesas būna stabilus.

Gauti detalių centravimo eksperimentinio tyrimo rezultatai patvirtino, kad vibracinis centravimas yra patikimas metodas, kuris gali būti taikomas automatiškai renkant detales, tačiau reikia tinkamai suderinti vibracinio žadinimo dažnį, amplitudę bei pradinę prispaudimo jėgą.

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EXPERIMENTAL INVESTIGATION OF PARTS VIBRATORY ALIGNMENT EXCITING IMMOVABLY BASED PART

Summary

Presented paper investigates vibratory alignment and matching of the parts being assembled automatically as immovably based receiving part is vibratory excited. Experimental setup for alignment of the parts having rectangular and circular cross-sections is given. Dependencies of alignment duration on excitation parameters, initial preload and axial misalignment for circular and rectangular chamferless parts are given. Areas of excitation and system parameters sets have been defined where the process of alignment is stable.

The obtained experimental data confirmed that investigated vibratory alignment is reliable method suitable for automated assembly of the parts, though requiring excitation amplitude, frequency and initial preload to be properly chosen.

Б. Бакшис, Й. Баскутене, А. Б. Повиленис

ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ ВИБРАЦИОННОГО ЦЕНТРИРОВАНИЯ ДЕТАЛЕЙ ПРИ ВОЗБУЖДЕНИИ НЕПОДВИЖНО БАЗИРУЕМОЙ ДЕТАЛИ

Резюме

В статье проанализирован вибрационный метод центрирования и сопряжения собираемых деталей при возбуждении неподвижно базируемой втулки. Представлена экспериментальная установка, которая использовалась при экспериментальном исследовании центрирования и сопряжения автоматически собираемых деталей прямоугольного и круглого поперечного сечения. Представлены зависимости продолжительности центрирования деталей от параметров вибрационного возбуждения, предварительного натяга и рассогласования осей. Составлены области сочетания параметров возбуждения и системы, при которых процесс центрирования стабилен.

Результаты экспериментального исследования подтвердили, что вибрационное центрирование является надежным методом и может быть успешно использовано при автоматической сборке деталей, но необходимо соответственно подобрать частоту и амплитуду вибрационного возбуждения, а также силу предварительного натяга.

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