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STRUCTURAL SCHEME OF ADAPTIVE SYSTEM OF CONTROL OF VIBRODRIVE OF A RESONANCE VIBROMACHINE

На основі розробленої структурної схеми, засобами різних мов програмування можна реалізовувати програмне забезпечення, котре в комплексі із мікроконтролером дасть змогу автоматизувати низку вібраційних технологічних процесів, забезпечити мінімальні енергозатрати на віброривід та оптимальні параметри технологічного процесу віброобробки.

On the basis of the developed block diagram, by means of different programming languages, it is possible to implement software, which together with the microcontroller allows to automate a number of vibration technological processes and ensure minimum power inputs on vibrodrive and optimal parameters of the technological process of vibration treatment.

Statement of the problem. The rapid development of equipment and technology causes the necessity of creation of energy-efficient, highly-effective and highly reliable simple vibration equipment for various technological purposes. Adaptive vibromachines [1] have a much higher potential than controlled [2] vibromachine, thanks to that they automatically provide and maintain energetically favorable resonance mode. Quite often they are the only way of the implementation of the one or another technological process at a given optimal level from the energetic and technological point of view. Therefore, work under the expansion of their technological capabilities and reduction of power inputs on vibro treatment is actual for the modern engineering and instrumentation technology.

Analysis of the recent research. In the given article [2], it is shown what perspectives and potential has control of parameters of vibration of operating devices of vibromachines with the aim of energy saving and implementation of defined technological processes. Adaptive vibromachines is a new class of vibromachines which allows to combine in its self the advantages of a separate control of parameters of vibrodrive of controlled vibromachines. In other words for to provide resonance mode owning to independent control of frequency of cyclic driving force of vibrodrive and maintain an amplitude of vibrations of the operating device at a determined level. Despite its undeniable advantages over controlled VTM (vibro technological machine) or circle resonance VTM (with certain coefficient of delay of vibration system) adaptive vibro machines still have disadvantages. In particular, in the algorithm of their work is [3] laid the uncertainty which is typical for extreme step-typed search systems. That is why realized adaptive vibro machines based on this algorithm of work have a low speed reaction on changes in the process of downloading of operating devise with the details and processing environment. In the works [4] and [5] proposed new methods of control of parameters of vibrodrives, which allows to create a double-circuit self-tuning adaptive vibromachines. The advantage of such methods of control is in that in the structure of the extremal control system there is no extremum search, but only tracking. Double-circuit principle of controlling of parameters of vibration fields of VTM can optimize the work of VTM in accordance with energy criteria on resonance mode and optimize the work of VTM in resonance mode in accordance with technological criteria. In the complex such approach to the structure of the control system allows to realize vibration technological process at the required quality level with minimum power inputs for vibrodrive.

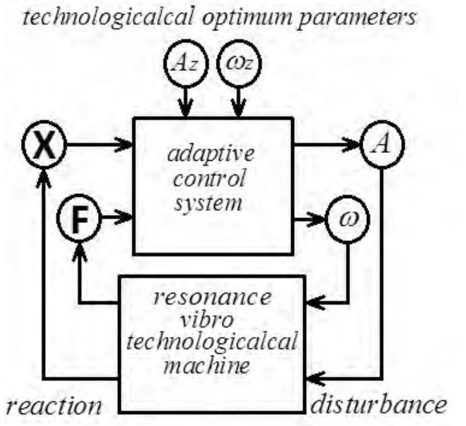

Fig. 1. Input and output parameters of adaptive system of control of vibrodrives of resonance vibromashines

Statement of the problem. The main aim is to elaborate a structural diagram of an adaptive system of control with the help of vibrodrive of resonance VTM, which will automatically provide a resonance mode of operating device of vibromachine thanks to tracking (and correction) of shift of phases between the amplitude of cyclic driving force of vibrodrive and reaction on him of operating device of vibromachine and which will make automatically correction of the parameters of vibrational field of VTM at the resonance frequency of work of operating device providing in such way stabilization in time of an optimal given criterion for quantative control of the parameters of vibrational field of operating device of vibromachine.

The main material. Figure 1 presents the general scheme of interaction of resonance vibromachine, operator of adaptive control system (ACS), the work of which is based on the methods of control [4, 5] and consists in double-circuit optimization of work of VTM according to energetic and technological criteria. In the process of realization of the structural control system in accordance with the methods described in works [4, 5] it is necessary to take into account the following. Change (correction) of perturbation influence of ω (frequency of cyclic driving force of vibrodrive) involves a change in the parameter F which is directly proportional according to the frequency ω, to the cyclical driving force of vibrodrive $F \cdot \sin(\omega t)$ and two elements of parameter X (amplitude of vibration of operating device of vibromachine) in particular to the amplitude of X and frequency of his changes ω which are interconnected $X(\omega) \cdot \sin(\omega t \pm \varphi)$ and change (correction) of perturbing influence A (amplitude of cyclic driving force of vibrodrive) causes change only of the amplitude of the parameter X. Optimal, from the technological point of view, are parameters(A_z та ω_z) for the realization of the technological process ,move directly to the ACS and because of the failure in time (during the cycle of vibro treatment) of equality $\omega_z = \omega$ the system conducts correction of parameter A based on the defined A_z and criteria of optimization and correction of a parameter ω the system conducts perpetually providing $\omega_0 = \omega$ (ω_0 resonance frequency of vibration system of virbo machine) that is resonance mode of VTM. Taking into account the physical connection [6] between the input (driving) values of amplitude and frequency of cyclic driving force of controlled vibrodrive, reaction of the amplitude on them, frequency and phase of vibrations of operating device of vibration technological machine and based on the ideology of control, which is set in works [4 , 5] was implemented a structural scheme (See fig. 2)of adaptive control system of vibrodrive of resonance vibromashines.

The principle of work of the proposed control system is as follows. The signal which is directly proportional to the frequency of vibrations of driving force $F \cdot \sin(\omega t)$ enters block 1, which is a comparator, where it compares with zero ($F > 0$). As the signal F, which is directly proportional to the frequency of vibrations of operating device, becomes larger than zero (point 48 in Fig. 2) than at the output of block 1 appears signal which moves to the input Set of blocks 3 and 8. Blocks 3 and 8 are the RS triggers and on the signal at the input Set sets up a logical unity on his output (if there is a clock impulse at the input C). The signal at the output of block 3 starts up block 4, which is a recorder t_n of clock impulses C. As soon as the signal F in the block 1, which is directly proportional to the frequency of vibrations of the operating device, will become less than zero (point 51) than at his output will be formed a logical zero, which is going to be inverted by block 2 into a logical unity which determines a logical zero at the output of block 3, which will stop the calculations of clock impulses t_n by the block of the recorder № 4.

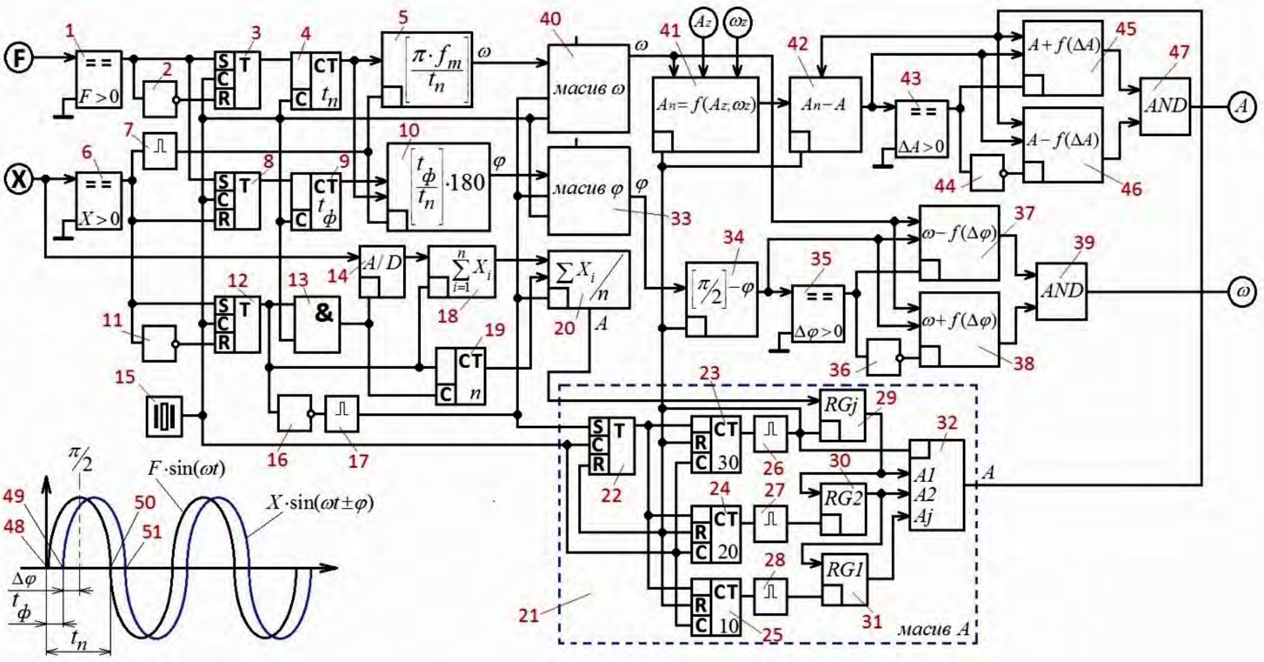

Fig. 2. Structural scheme of adaptive control system of vibrodrive of resonance vibromachine

Taking into account the fact that vibrations in the mechanical system of vibration technological machine are forced, the operating device fluctuates with the frequency of driving force. The signal $F \cdot \sin(\omega t)$ is directly proportional to the frequency of driving force, that is to the frequency of vibrations of the operating device of vibromachine and during half-period of his vibrations in block 4 was conducted calculation t_n of the amount of clock impulses C. Simultaneously with the start of half-period of vibrations of the operating device of vibromachine, at the output of block 8 was set a logical zero, which sets up calculation of the number of clock impulses t_ϕ by block 9. Taking into account the condition before resonance starting of a vibromachine (see diagram in Fig. 2) with any arbitrary before resonance frequency, less or much less from the given technologically optimal ω_z or resonance frequency according to [4, 5, 6] in defined working mode, the phase of an amplitude of vibrations in operating device of vibromachine will drag behind from the amplitude of cyclic driving force at the quantity less than $-\pi/2$. Therefore, the response of vibromachine $X(\omega) \cdot \sin(\omega t - \varphi)$ to cyclic perturbation of vibrodrive is checked in block 6. Block 6 is a comparator, where the checking of the fulfillment of condition $X > 0$ is done. The fulfillment of the given requirement will result in setting up of a logical zero at the output of block 8, stoppage of calculation of the number of impulses t_ϕ by block 9 and setting up by block 7 of arithmetic operations on the data from blocks 4 and 9 in the arithmetic blocks 5 and 10. In block 5 during each period (see diagram in Fig. 2) implements the calculation of frequency of vibrations in the operating device of vibration technology machine on the basis of the following considerations:

$$\omega = 2\cdot\pi\cdot f = \frac{2\cdot\pi}{T} = \frac{2\cdot\pi}{2\cdot(t_n\cdot T_m)} = \frac{2\cdot\pi}{2\cdot(t_n\cdot(1/f_m))} = \frac{\pi\cdot f_m}{t_n}$$

where f_m the frequency of clock impulses (block 15). In block 10 during each period of vibration of the operating device of vibration technology machine, including work (interaction) of the mentioned blocks and number of fundamental principles of the theory of vibration , the definition of phase φ of the amplitude of vibrations of operating device of TMV with regard to the amplitude of cyclic driving force of vibrodrive is conducted. Phase φ is determined on the basis that for any ω_0 operating frequency of vibrations of the operating device of vibration technology machine if $\varphi = \pi$ (see diagram in Fig. 2), than this corrects to the time:

$$\frac{T}{2} = \frac{(t_n\cdot T_m)}{2} = \frac{(t_n\cdot(1/f_m))}{2} = \frac{t_n}{2\cdot f_m} \qquad \text{that is when } \varphi = \pi = \frac{t_n}{2\cdot f_m}$$

For the real value of φ phase of amplitude of vibrations in the operating device of VTM with the regard to amplitude of cyclic driving force of vibrodrive the time will be determined as $t_\phi/(2\cdot f_m)$ so after forming of simple proportion (ratio) we can easily calculate the phase φ :

$$\begin{array}{lcl} t_n/(2\cdot f_m) & \rightarrow & \pi \\ t_\phi/(2\cdot f_m) & \rightarrow & \varphi \end{array} \quad \text{where from } \varphi = \frac{(t_\phi/(2\cdot f_m))\cdot\pi}{t_n/(2\cdot f_m)} = \frac{t_\phi\cdot\pi}{t_n}.$$

After the completion of the half-period of vibrations (point 50) of the signal directly proportional to the frequency of vibrations of driving force $F\cdot\sin(\omega t)$ by block 7 was given a command to blocks 5 and 10 to calculate the frequency ω of cyclic driving force of vibrodrive) and phase φ of amplitude of vibrations in operating device of VTM with regard to the amplitude of cyclical driving force of vibrodrive. During the all half-period of the reaction of vibromachine $X(\omega)\cdot\sin(\omega t-\varphi)$ on cyclic perturbation of vibrodrive was delivered by an analog-to-digital converter (block 14). Digitization of this signal is made within one half-period. It is provided with that as soon as the condition $X > 0$ (point 49) is fullfiled at the output of block 12 is going to be formed a logical unity which will allow to pass by a clock pulse through the logical key (block 13) from block 15 and provide digitization of a signal $X(\omega)\cdot\sin(\omega t-\varphi)$ with frequency of discretization f_m by the block ADC (14). Clock pulses at the output of a logic key 13 in conjunction with the ADC enter the clock input of the recorder of block 19. The logical unit at the output of block 12, which appeared at the beginning of the half-period of the signal $X(\omega)\cdot\sin(\omega t-\varphi)$ allows to make counting of clock pulses of block 19 which are the frequency of discretization f_m for ADC and provides a summation of each i – the meaning of the digitized value $X(\omega)\cdot\sin(\omega t-\varphi)$ (with frequency of discretization f_m) by the summation block 18. Non-fulfillment of condition $X > 0$ (point 51) will automatically install the logical unit at the output of block 16 (block 11) to the output Reset of the block 12 and closes a logical key 13, which will stop digitalization of signal , the reaction of vibromachine $X(\omega)\cdot\sin(\omega t-\varphi)$ to cyclic disturbance of vibrodrive by the ADC 14 will stop the summation of discrete values of the given signal in the block 18 and the stop counting of clock pulses (discrete values of digitized quantity $X(\omega)\cdot\sin(\omega t-\varphi)$ which were summarized by block 18) by block 19. Non-fulfillment of condition $X > 0$ (point 51) will automatically install the logical unit at the input of block 16 and forms a command for triggering by block 17. On command from block 17 in block 20 will be calculated an amplitude A, as an average value (arithmetic mean value or half-period area) of the signal reaction of the operating device of vibromachine $X(\omega)\cdot\sin(\omega t-\varphi)$ on cyclic perturbation of vibrodrive. Inspite the calculation of amplitude A in block 20 at the command from block 17 is given permission to start work by three blocks (block 21, block 33 and block 40) the internal structure and principle of operation of which are identical. Accordingly, block 40 (the array ω) handles such parameter of vibration technological machine as the frequency of vibrations in the operating device , block 33 (the array φ) handles such a parameter of vibration technological machine as the lagging of phase of the amplitude of vibrations in the operating device of VTM relative to the amplitude of cyclic driving force of vibrodrive and block 21 (the array A) handles such a parameter of vibration technological machine as amplitude of vibration of operating device of VTM. The structure and principle of operation in the given blocks are identical, so that is why Fig. 2 showes in detailes work of block 21. On the command from block 17 at the output of block 22 is set up a logical zero, which allows to count clock pulses of blocks 25, 24, 23. The first , which will count to the specified value (10) will be block 25 on the basis of which the block 28 will give the command to block 31 to record his own data ,which is stored in block 30. Second, to the number (20) the clock pulses will count the block 24 and on the basis of that block 27 will give the command to block 30 to record in its register an information which is stored in block 29. Recently, the last which will count to the specified value will be the block 23 , on the basis of that the block 26 will form the command to record information for block 29, for zeroing of the value of the recorders 25, 24, 23, 22, and for processing of statistical operations of array data $RG1 \cdots RGj$ in block 32. Th number of registers $RG1 \cdots RGj$ that is the number of points which is taken into account in determining the real, rather than instantaneous meaning of certain quantity is determined for each case and depends on the characteristics of vibration dissipative mechanical system (that is from the moment of the vibrations in the system, which depends on the coefficient of damping, logarithmic decrement damping and damping factor). The necessity to take into account the last RGj and several next to last points $RG1, RG2$ of certain dynamic values (ω, φ , A) due to the fact that duringvibrayions of the operating device (camera, U – like containers, bunkers) loaded by the working environment (balls, prisms, ...), details, free-flowing environment (rocks, ...) the giver of vibrations wil record laying on of many instant harmonics from accidental bumps in operating device. So to judge and draw a conclusion about the general dynamic state of vibrational system on any casual instantaneous value (ω, φ , A) and give the command for correction of a given perturbing parameter of controlled vibrodrive on this basis will be illogical. For example, if an adaptive control system works with vibrational technology machine, the resonance frequency of vibrations of which is 50 (Hz) then in the analysis mentioned above, for an hour in 1 second the system will have 50 points. Holding of 50 corrections in 1 s. of amplitude of driving force of controled vibrodrive concerning vibrational mechanical system of vibro machine is not reasonable because if a given level of amplitude of vibrations is 2.5 (mm) (for the given ω_0), and casual instantaneous values 2.49, 2.51 then the correction will further perturb vibrational mechanical system of vibro machine that will decrease the resistance of controled object. In the case, when 5 points are taking into account from the last, than for 1 second it is possible to conduct up to 10 corrections of amplitude of driving force of controlled vibrodrive, and depending on the mathematical vehicle of the block 32 reaction to casual values 2.49, 2.51 can never be hold. Mathematical vehicle of the block 32 may be made in the way that it will does not react to the misserable accidental variations in a given parameter (it may have hysteresis and don’t react to changes that do not exceed the quantity of hysteresis) and objectively react to constant and misserable change of the given parameter. That is, if the latter, and the two previous points (out of five) received instantaneous amplitude of 2.51 then in thevibrational system it is easy to define the increase of the amplitude of vibrations in operating device of vibromachine. In favor of the proposed method, which is based on the processing of array data $RG1 \cdots RGj$ in block 32, affirms that for example the time of a cycle of vibroabrasive processing has dimension within an hour. Processing within one hour at the wrong (suboptimal) value ($A \neq 2.5$ mm) of amplitude of vibrations of the operating device will be a reason for defective final products. Correction in measure 10 times for 1 (s.) during 1 (h.) is sufficient for the objective obtaining of final products of satisfactory quality. In the same way as in block 21, the processing of his arrays will conduct the blocks 33 and 40. As a result, the control system will receive objectively weighted values of dynamic variables (ω, φ , A), which characterize the state of a certain technological process at this stage of vibro treatment. The values of the frequency of vibrations of ω in the operating device of vibromachine comes into three blocks – 41, 37 and 38. The value of lagging of phase φ of the amplitude of vibrations of operating device of VTM with reference to the amplitude of cyclic driving force of vibrodrive enters the block 34. On command from block 21 (which indicates that the operation in blocks 21, 33 and 40 came to end) the blocks 34, 41 and 42 begin calculations. The block 34 determinates the quantity of lagging or outstripping $\pm\Delta\varphi$ of the amplitude of vibrations in operating device of VTM relative to energy efficient resonance mode at a given frequency of vibro treatment. The parameter $\pm\Delta\varphi$ is passed immediately to three blocks 35, 37 and 38. Block 35 checks the implementation of equality $\Delta\varphi > 0$

and then the precision is fair, this affirms that the lagging of phase φ of the amplitude of vibrations of the operating device of VTM is relative to the amplitude of cyclic driving force of vibrodrive more than the optimal value $-\pi/2$. In such case, the frequency ω of cyclic driving force of vibrodrive is necessary to correct in the direction of extenuation. Therefore, the fulfillment of the condition of equality $\Delta\varphi > 0$ in block 35 will cause setting of a logic zero at its output and will perform the correction of frequency ω of cyclic driving force of vibrodrive in block 37 in the direction of its reduction ($\omega - f(\Delta\varphi)$). Non fulfillment of condition in the side 35 indicates that the lagging of phase φ of the amplitude of vibrations in the operating device of VTM with regard to the amplitude of cyclic driving force of vibrodrive is less than optimal value $-\pi/2$. Therefore, at the output of block 35 will appear a logical zero, which is going to be inverted by block 36 and a logical unit, at his output, will start an operation in block 38 where the correction of frequency ω of cyclic driving force of vibrodrive in the direction of increase $\omega + f(\Delta\varphi)$ will be conducted. Information about the new corrected optimal from energetic point of view, value ω of the frequency of cyclic driving force of vibrodrive through the block 39 comes out of the system and moves to the system of vibrodrive VTM. The block 41 will make calculation A_n of the required value of the amplitude of vibrations in the operating device of vibro machine at the existing frequency of vibro treatment. On the basis of the given (A_z, ω_z) optimal, from technological point of view, dynamic parameters of the operating device of vibro machine, the real operating frequency of vibro treatment ω and given criterion of optimization, is made calculation A_n . This value moves directly to the block 42 where from it subtracted the real value of the amplitude of vibrations in the operating device of vibromachine at a given frequency ω of vibro treatment. The result of the subtraction ΔA is checked for accomplishment of equality $\Delta A > 0$ in the block 43. If ΔA is more than zero, than it means that the needed A_n is optimal to the value of amplitude of vibrations operating device, at the given frequency of vibro treatment should be greater than the existing A.So while performing the condition $\Delta A > 0$ at the output of the block 43 will appear a logical unity , which will cause execution of arithmetic operations in block 45, where the correction of amplitude of cyclic driving force of vibrodrive in the direction of increasing ($A + f(\Delta A)$ Non-fulfillment of condition in block 43 will cause appearance of a logical unit at the output of 44, which will become a reason for execution of arithmetic operations in the block 46, where will be conducted correction of the amplitude of cyclic driving force of vibro drive in the direction of decrease ($A - f(\Delta A)$).

Conclusion. It was elaborated a structural scheme of adaptive control system of vibrodrives of resonance VTM which is able to ensure automatically a resonance mode of operating device of vibromachine ; thanks to tracking (and correction) of shift of phase between the amplitude of cyclic driving force of vibrodrive and reaction on him of operating device of vibro machine. It automatically conducts correction of parameters vibrational field of VTM on resonance frequency of work of operating device, in such way it provides stabilization in time of optimal, the given before, criterion for quantitative estimation of parameters of vibrational field of operating device of vibromachine. On the basis of the proposed structural schemes, by means of different programming languages , it is possible to implement software, which together with micro control will allow to automate a number of vibrational technological processes, ensure minimal energy expenses on vibrodrive and optimal parameters of technological process.

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IMPROVEMENT OF CONSTRUCTIVE SCHEMES AND CALCULATIONS OF OSCILLATION TUBULAR CONVEYERS

Розглянуто питання створення вібраційних трубчастих конвеєрів, запропонована методика їх розрахунку. Вібраційні трубчасті конвеєри, дають змогу розширити технологічні можливості шляхом забезпечення транспортування сипких продуктів і утворення на їх базі транспортуючих ліній. Розглянуті основні вимоги на етапі проектування цих вібраційних конвеєрів, для забезпечення коливального руху і наведені різноманітні схеми кріплень пружних систем та експериментальні графічні залежності.

In this article the question of creation of oscillation tubular conveyers, has been considered and offered the method of their calculation. Oscillation tubular conveyers allow to extend technological possibilities by providing transportation of free-flowing products and to create on their base transport lines. The basic requirements are considered on the stage of designing these oscillation conveyers for providing fluctuating motion, and various schemes of mounting of the resilient systems and experimental graphic dependencies have been presented.

Introduction. Application of oscillation tubular conveyers with an electromagnetic drive in many industries for the purpose of transporting friable, lump, artificial materials and products in many cases is significantly more effective than the use of other types of conveyers. This is due to the following basic advantages:

1. Constructive simplicity of vibroconveyers.
2. Small consumption of power due to around resonance work mode.
3. Simplicity of adjusting and commissioning of conveyers working parameters.
4. Possibilities of reverse vibrotransportation for conveyers with elliptic law of motion of transported elements.
5. Reliable work in the conditions of gassed, dusted, and other similar environments.

Despite mentioned and also other advantages these devices have not received wide application. This can be explained due to the absence of serial standard highly productive conveyers on the market, lack of education of production workers and production managers about this effective technique and its possibilities, and extremely low amount of specialists in this field.

Also here can be added the unwillingness of private entities to implement the new technique, and to invest in this and many other directions of new and effective techniques.