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Holographic interferometry for investigation, optimisation and design construction of wave mechanical system

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Introduction

The waves and vibrations are encountered everywhere, in the living and non living nature, in engineering.

The atoms, molecules, oceans, planets, galaxies, cosmic space, cells of living organisms, separate organs and the organism as a whole do perform wave motion. It is important for the mankind to use effectively the waves arising in nature as a power source or as the working organs for the execution of technological processes. Besides the principles of motion of living organisms are also important in engineering creating technological processes and devices of new types.

In order to implement this successfully it is important to analyse the ways of motion of living nature and on their basis to create the principles of action of the corresponding technical devices. In engineering the vibrational and wave technology and the devices devoted for this purpose are becoming more and more widespread. For the successful development it is necessary to perform the research of dynamics of wave mechanical systems in order to reveal the nonlinear qualities of those systems, to create the calculation - design methods, to develop the experimental methods of propagation and analysis of wave processes, to analyse systems of separate types.

For the displacement of bodies various types of waves are applicable, for example standing, traveling, harmonic or damped, solytons, one dimensional, two dimensional and multidimensional, straight linear, spiral and etc. waves. They are the most widely used types of waves for the displacement of bodies in engineering. The displaced bodies may be a material point, a cylinder, an unbalanced with respect to the geometrical axis cylinder, a body of rigid beam type, one dimensional and two dimensional chains of bodies

The scientific and technical progress poses problems in the development of new perfect mechanisms and machines of advanced type, namely quick operational speed, controllability, precision, reliability, compactness. The mechanical systems with wave excitation are perspective for this purpose.

The basis of the mechanical system theory are developed by Blehman I., Lavendel E., Goncharevich I., Neimark J., Poturajev V., Babickij V., Povidailo V., Frolov K. and many other scientists. Though in the theory of this system despite the fundamental results obtained by Vesnitskij A., Ganijev R., Ulitko G., Tokar A., Dobroliubov A., Utkin R. and others, and also the applied results by Bansevichius R., Kurilo R., Poturajev V., Barauskas R., Ostađevičius V., Kulvietis G. and many others, many problems do remain unsolved.

The main pupose of paper to develop the methods of holographic interferometry for investigation of wave mechanical systems and perform investigations of that systems.

The holographics methods and methodologies for analysis of wave mechanical system where not enough developed. Usually the way for interpretation and analysis interference fringe patterns depends from type of vibrating waves, the types of waves and vibrations taking part in wave mechanical systems. Different types of waves are applied in different approaches for the holographic analysis

In this way it is important to develop theory for interpretation of fringe patterns of vibrating links of mechanical systems according to optical parameters and holographic principles, and the boundary conditions, materials of links, and the vibrating processes taking part in real constructions.

Laser holographic interference methodology is a powerful and effective tool for design analysis and optimisation of operation of such different kind of systems. In some cases this is the only possible tool of analysis (adaptive optics mirrors), in other cases it is a good and effective tool of analysis, which in some instances exceed the possibilities of other research and monitoring methods [1-9].

Some of the applications presented in the following paper were implemented under research supervision of large group of companies, others were initiated by foreign partners. It could be mentioned that many projects were implemented in former Research Center “Vibrotechnika”, others, already after reconstruction of independence of Lithuania. Examples could be co-operation with Ancona University in Italy, Daimler Crysler and Ford research institutes in the USA.

Optimisation construction of vibromotor

The object is presenting the advances in the design of vibromotors using holographic interference methodologies. The application areas of vibromotors varies from precision actuators upto optical positioning devices in aerospace. The vibromotor itself is interpreted as a mechatronic system consisting from a pjezoelectrical actuator and the driven object. The overview of the designs and practical implementations of of vibromotors is presented in the paper. The principle of design covers areas from utilising standing deformation wave energy and propagating wave energy. The specifics of vibromotors is achieving high precision levels in the motion of the driven object. The only way for increasing the accuracy levels of vibromotors is exploiting specific geometric shapes of materials for the actuator and especially in the contacting zones. Laser holographic interference method is used for determination and control of working characteristics of vibromotors (eigenshapes at appropriate resonance frequencies, transfer of waves in the contact zones, etc.). The experimental data.is later used as source data for numerical optimization of the designs of vibromotors

The analysed types of vibromotors [11] are operating on the principle of high frequency micro impacts happening in the contact zones. The impacts are generated by pjezoelectrical actuators which perform the role of driving elements. The driven elements are either straight beams in straight linear motion vibromotors, or round rotors in angular motion motors (Fig.1.a). The principle of operation is displayed in Fig. 1.b(Ref.[11]).

The optimal application of vibromotors requires the knowledge of dynamic characteristics in case of uniform and stepwise modes of operation, sensitivity, limit velocity characteristics, etc.

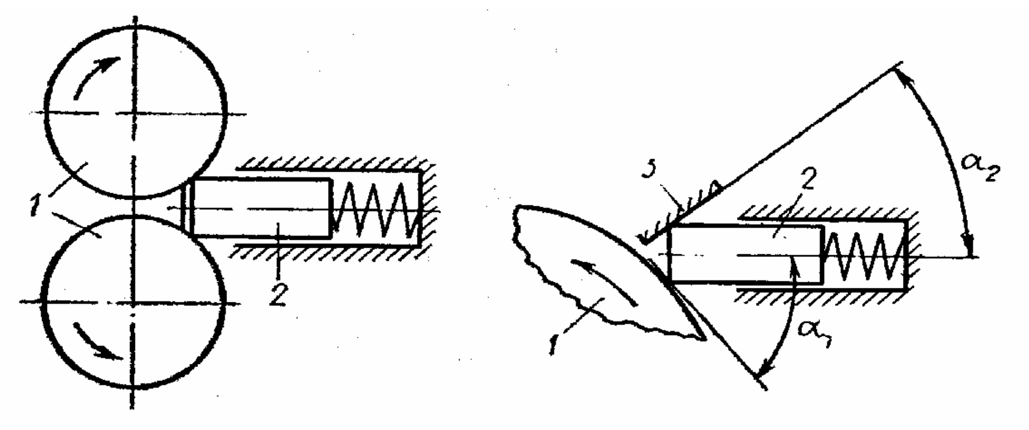


Fig. 1. **a) Principal schemes of vibromotors. Vibromotors transforming one component vibrations in the contact zone to linear or angular motion: 1 - rotor, 2 - transformer of longitudinal vibrations, 3 - fixing mechanism. Angles α_1 and α_2 depend from the reological features of rotor and fixing mechanism**

The main general characteristics and parameters of vibromotors could be the followings ones:

a) Mechanical characteristic of vibromotor:

$$V_c = V_c\left[F_e, U_i\left(f_i, U_{0i}, \varphi_i\right)\right],\ i = 1,2,... \qquad (1)$$

here V_{0i} - driving voltage amplitude; V_c - linear velocity of the mobile part of vibromotor; θ_i - phase of oscillations; x, y, z - co-ordinates of the driving actuator in the contact zone; y_0 - amplitude of the oscillations of the driving actuator; x_1, z_1 - amplitudes of the oscillations of the driven part.

Mechanical characteristic of vibromotor defines the relationship between the linear velocity of the mobile part V_c and external loading at the contact zone F_e, and parameters of feeding voltage (frequency f_i, amplitude U_{0i}, phase φ_i). V_c is equal to the velocity of the mobile part in the linear vibromotors. In rotation vibromotors $V_c = R \cdot \frac{d\varphi}{dt}$, here R - the radius of contact zone, φ - angle of rotation, t - time. External loading force F_e is defined by the ratio $F_e = M_e / R$, here M_e - moment of external loading.

b) Mechanical characteristic of the contact:

$$V_c = V_c\left[F_e, \varsigma_i\left(f_i, S_i, \theta_i\right)\right],\ i = 1,2,... \qquad (2)$$

which defines the relationship between the linear velocity of the mobile part V_c and external loading F_e, and parameters of oscilation of driving joints in the contact zone (frequency f_i, amplitude S_i, phase θ_i). This equation characterises the transformation of vibrations to an uniform motion.

c) Parameter identifying the rigidity of fixation of the mobile (driven) part when the vibromotor is not operating.

d) Parameters identifying the viscous and dry friction in the contact zone between the driven and the driving part.

e) Parameter identifying smallest controlled linear step of the driven part.

f) Parameter defining the relation between V_c and the contact angle a displacement of the driving units.

g) Parameter showing the efficiency of mechanical energy transfer from driving to driven unit.

The whole set of parameters may be exploited to define the macro-characteristics: operation-ability, accuracy, response-ability, motion trace ability.

The defined parameters are to be measured and calculated for the following regimes of operation - when the driving part is rigidly motionlessly fixed, and when the driven part perform the linear motion. Such methodology secures better accuracy and perfection of design. Holography interferometry methods are used for the extraction of objective experimental characteristics of the working regimes, what later gives guidelines for optimisation of the design of vibromotors.

The applied laser holography methods have to be different for the two working regimes. In the first case, when the output (driven) part is motionlessly fixed, it is possible to use the laser with continuous beam. In that case the method of real time data processing is used, the motion of objects is averaged in time and time modulation is used (real-time strobohology).

That method can be applied, as the driven part is motionless, and the processes happening in the contact zone between input and output links do not give rise to longitudinal motion, and do not affect the optical transformation. In case when the driven part is performing longitudinal motion (each of them can differ by its character) the holography method must use following procedures - impulse holography with compensation of motion of the analysed object.

The analysis of holograms and interpretation of results has been performed using methodologies presented in the publication[11-12].

Fig. 2 shows the schematic construction of the vibromotor operating on the principle of side high frequency micro impacts. Fig.3 shows the scheme of compensation of motion of the driven link. Fig. 4. holographic interferograms of reverse vibromotor of angular and linear motion.

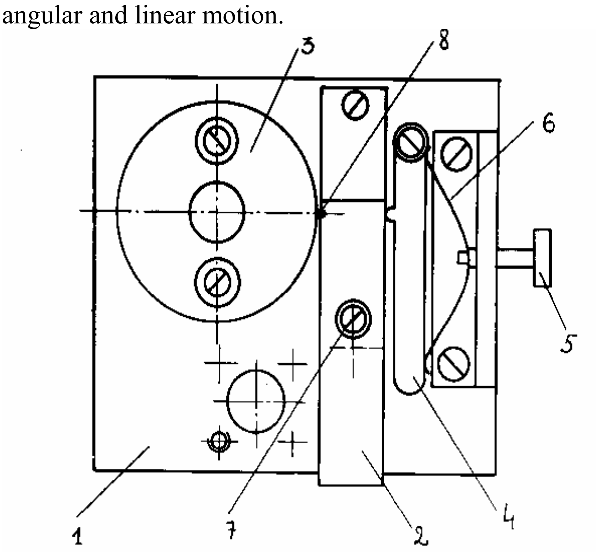


Fig. 2. **Reological model of reverse vibromotor of angular and linear motion: 1 - body, 2 - actuator, 3 - rotor, 4, 5, 6 - pressing attachment, 7 - actuator's fixing, 8 - contact zone**

The results of experimental analysis of vibromotors operation are presented in photos of holograms showing the different regimes of operation. Fig. 4 shows the holograms of the rotation and linear vibromotors. Fig. 4 (1) and Fig. 4 (2) show the vibromotors which driven parts are fixed. The control voltage U = 100 V, f = 23,45 · 10^3 Hz is brought up to electrodes of piezoelectric actuator which is pressed by constant force F_e = 0,8 N in the contact zone. It can be seen, that when the voltage is applied to the electrodes 2 - 4 in Fig. 4 (2) (reverse mode), the amplitudes of perpendicular oscillations are lower. Due to this fact, the angular velocity of the driven rotor is lower. As the further analysis shows, that is primarily related with the loading forceF_e.

Fig. 4 (3) and Fig. 4 (4) show vibromotors with fixed driven parts at following feeding voltages - U = 80 V, f = 21,37 · 10^3 Hz and 18,20 · 10^3 Hz, F_e = 0,8 N. It can be noted, that the variation of frequency enables to find 18,20 · 10^3 Hz - regime where the shape of the oscillations tend to be optimal (compared with Fig. 4 (1)). i.e. the nodal line is already formed in the left part of the driving element, nodal line is forming itself in the zone of fixing, but in the contact zone it is almost vanishing.

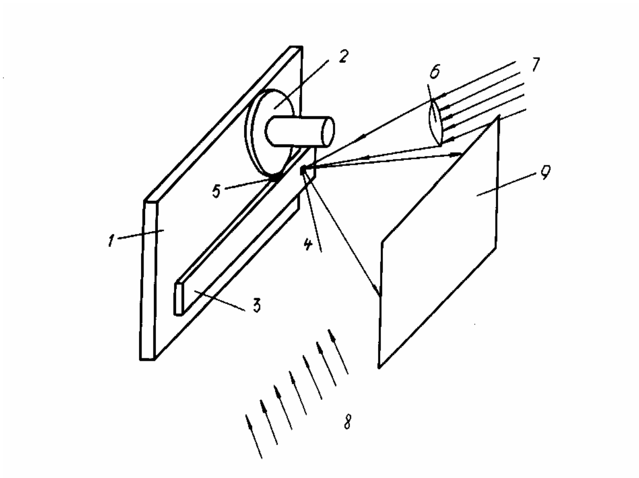


Fig. 3. **Schematic diagram of the compensation of the object's motion during the exposition time: 1 - body of vibromotor, 2 - rotor, 3 - actuator, 4 -mirror, 5 - contacting element, 6 - focusing system, 7 - reference beam, 8 - object beam**

Fig. 4 (5) and Fig. 4 (6) show the vibromotors with fixed driven parts at different amplitudes of feeding voltage - U = 80 V and U = 45 V. Other parameters are same - f = 23,45 · 10^3 Hz and F_e = 0,8 N. It can be clearly seen that the higher voltage does not lead to the better operation regime. At U = 80 V the normal amplitude components in the contact zone are sufficiently lower than in the optimal case (Fig. 4 (1)). Fig. 4 (6) shows the vibromotor in the non-operative mode, as the amplitude of voltage is not succeeding originating the appropriate form of oscillations.

Fig. 4 (7) - Fig. 4 (12) show holograms of the vibromotor with the rotor in motion. Interferometry holograms are produced using pairs of laser impulses.

The delay time of. the second impulse is 20 μs. The optimised parameter in this case was the placement of the driving elements. Fig. 4 (7) shown the starting moment of vibromotor: there are no interferometric lines on the rotor - it shows that in the starting moment the rotor is motionless. Fig. 4 (12) clearly displays that the interferometric lines show that the rotor is not sufficiently fixed. This is due to too small loading force acting at the contact zone.

The application of laser interferometry holograms enables the optimisation of the construction of vibromotors. It is relatively easy and very effective mean for vibromotor characteristics investigation. In this case the set of vibromotors analysed characteristics is much broader that only direct characteristics of motion produced by ordinary tests. Moreover, such kind of analysis does give guidelines not only for optimisation of vibromotors, but together with analytical and numerical analysis may lead to the design of new and more sophisticated mechanisms.

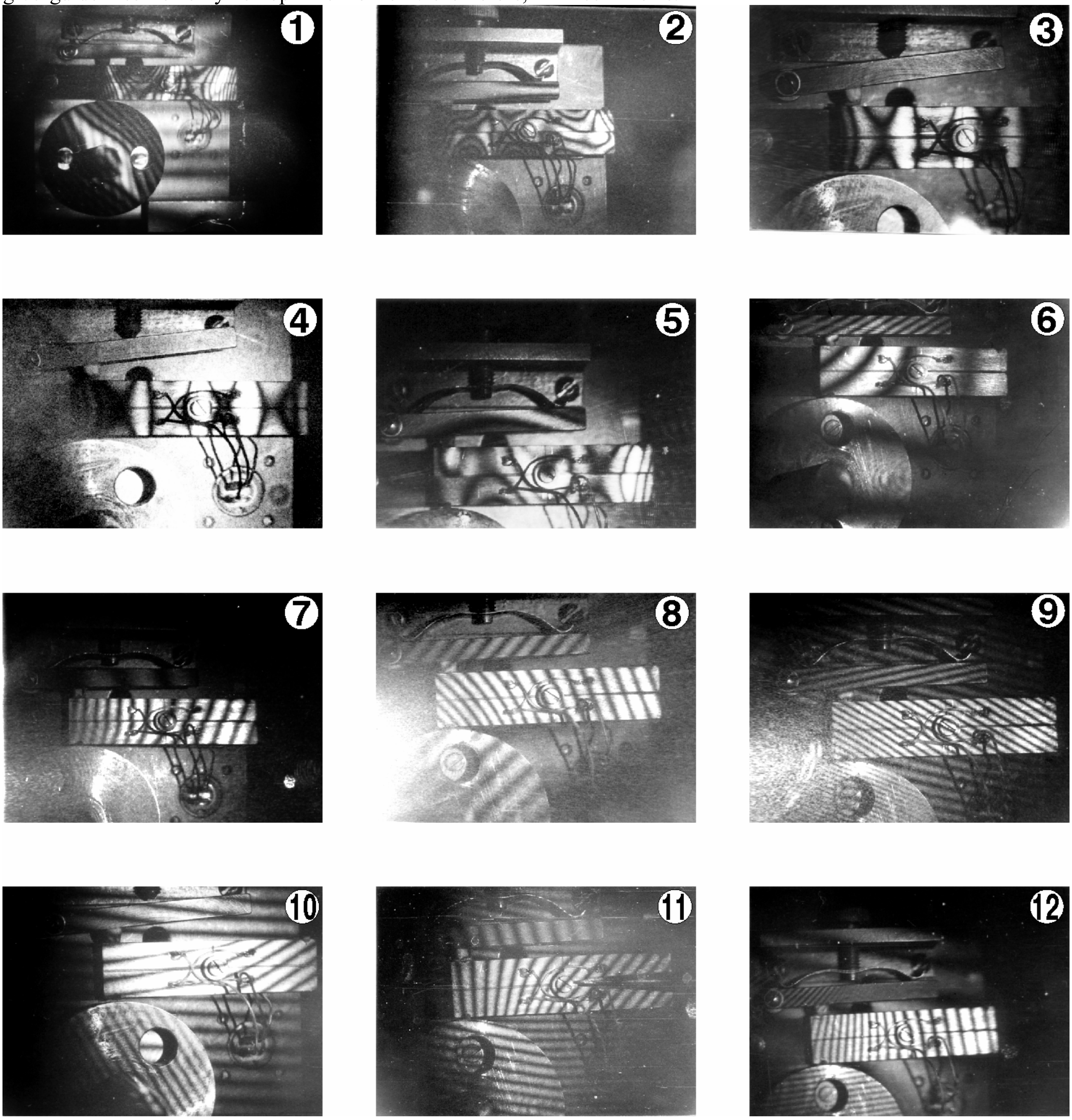


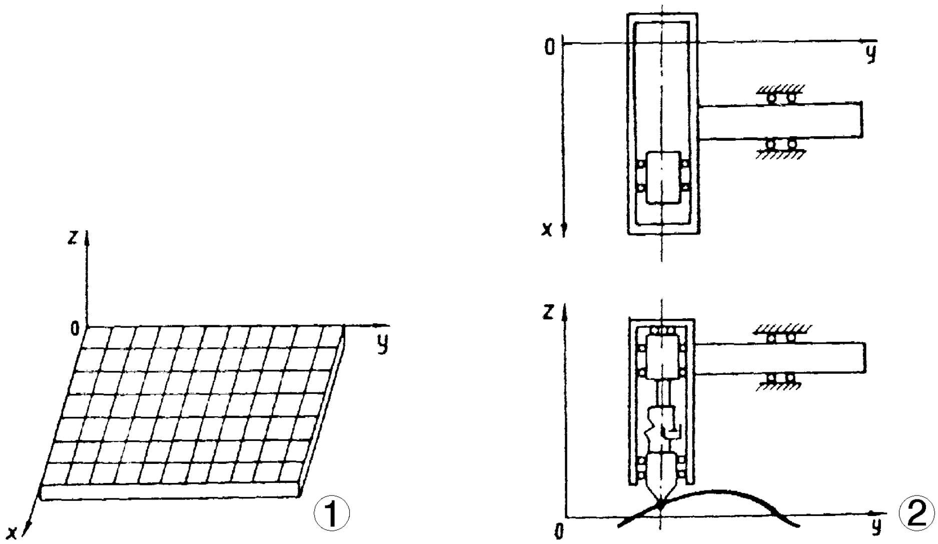
Fig. 4 **Holographic interferograms of reverse vibromotor of angular and linear motion**

Investigation the links of the wave transport system

The development of wave transport system is presented in publications [13-14]. The original two coordinate step wave motors of synchronous type are analyzed. In then the output member is pushed by the standing waves excited in the input member. The input link may be a rectangular plate or a cylinder or similar. The output member is pressed to the working surface of the input member by elastic-dissipative elements. The positions of nodal and peak points of the input member may be changed in various ways.

The created models and the performed research of the dynamics determine the characteristics of those systems.

The experimental research is complicated because in the input member for example in case of rectangular plate besides of the orthogonal standing waves the waves of various frequencies traveling and non orthogonal and damped type arise. That's why for the solution of those problems the method is created based on the method of laser holography and the research is performed.



The step motor the input member of which is of shape of the rectangular plates is analysed in fig 5 (1).

It's vibrations are excited by piezocrystals the lines division of electrodes of which are parallel to the axes Ox and Oy. The output member of the motor is pushed by the input member by using the element pressed to the profile perfoming wave motion Fig. 5 (2).

Fig. 5. **(1) - Input member of the step motor; (2) - step motor**

So the stable regimes of the pressing member before the resonance are those when the contact points of the input and output members are at the nodal points of the input member, and after the resonance – at the points of maximum deflections. After the resonance it is the opposite [15].

When analysing the performance of links of wave transportation systems it is necessary to investigate the wave characteristics of the input member, its influence to the other elements of the system (see fig. 6).

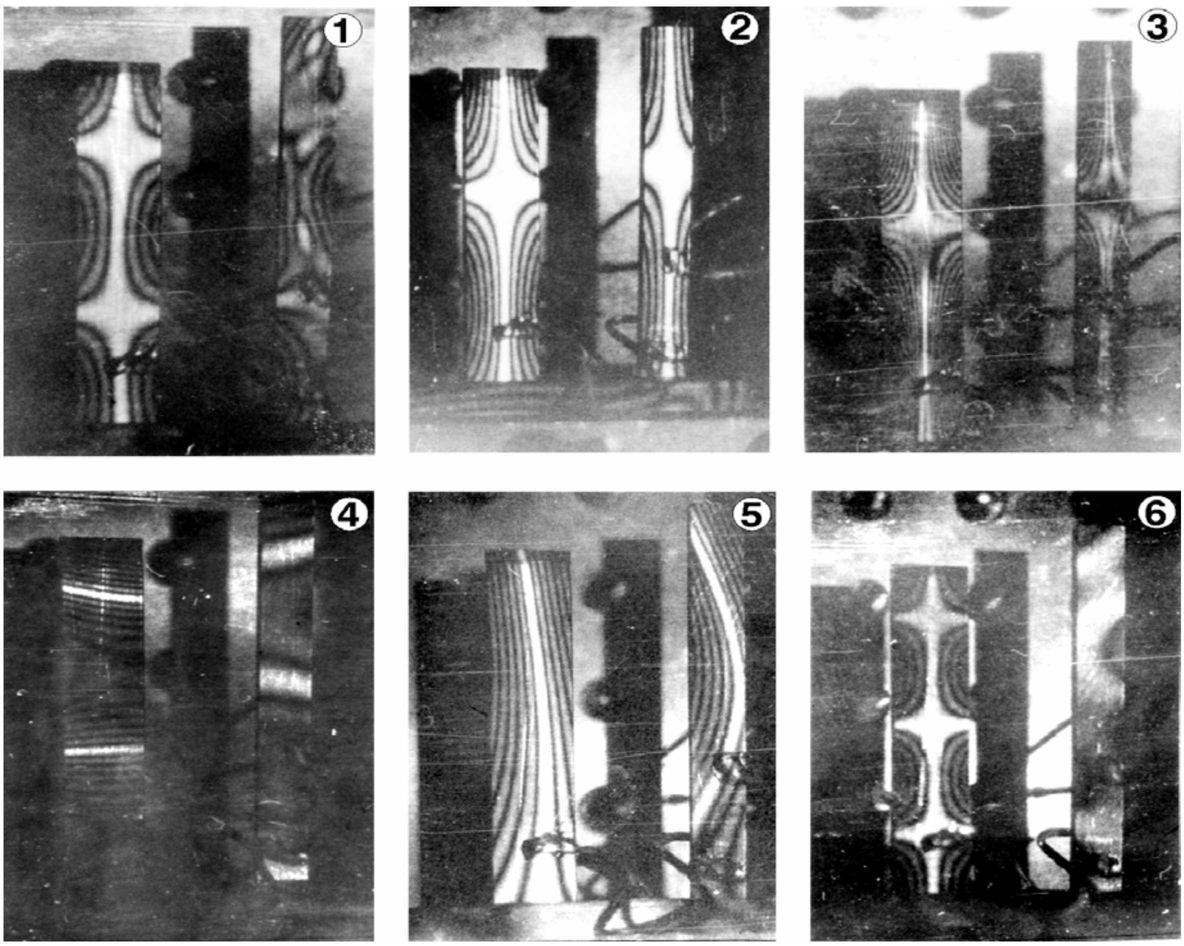


Fig. 6**. The input member (piezoceramics plate) holographic interferogram of transport system. (1) – 9.120 kHz; (2) – 6000 kHz; (3) – 6100 kHz; (4) – 10200 kHz; (5) – 5000 kHz; (6) – 15000 kHz.**

The performed holographic research and the performed analysis of wave transportation systems according to the experimental data enabled to create the transportation systems of the principally new type. The experimental research of transportation systems with the use of holographic interferograms enabled to determine the reasons because of which lateral, of damped type and traveling waves are generated and this enabled to eliminate then thus enswing the dynamical stability and precision of the performance of transportation systems.

Holographic interferogram was made for the optimization parameters input member (resonance frequency, geometry of input member, amplitude exciting and others).

The wave step two coordinate motors of synchronous type based on exitation of standing waves have been proposed. According to the eigenfrequencies of the input member they may be of resonance type.

It is determined that the stability of the output member depends on the difference of it's eigenfrequencies and forced frequencies. In the regime before the resonance stable regimes are when the contact point of the input and output members is located at the nodal points of vibrations, and in the regime after the resonance – in the points of maximum deflection.

Determination of energy transfer in contacting links

Problems of energy transfer in mechanisms with wave excitation do find actuality in many applications of vibromotors and actuators, where the generated motion of the active parts is transferred to the motion of the working parts through the contact points or zones.

Experimental analysis of the dynamics of such systems in transitional and steady state regimes is performed. The purpose of the work is to determine the dynamical processed in analysed systems, the transformation of the waves existed in the body before and after the output link. The presented method based on holography enables not only to perform research, but also to optimise the systems.

The results of research of the system, the input link of which is an elastic beam and the output link - a rigid body or cylinders is presented [16] The output links are elastically or rigidly pressed to the input link.

Transfer of energy is analysed in a one dimensional beam with longitudinal and transverse harmonic excitations at one end of the beam and damping of the generated vibrations at the other end of the beam. The middle part of the beam is point-loaded with external spring - absorber joint which simulates the contact point with the movable part of the system.

The displacement waves generated by external excitation force at the end of the beam are propagating alongside the beam, passing through the contact joint, and are damped in the end part of the beam.

The experimental analysis of a piezoelectric plate contact was performed using holographic interferography what enables clear investigation of the wave processes caused by the contacting links.

The piezoelectrical beam is activated the harmonic charge oscillations at the end of the beam. The harmonic propagating waves partially reflect from the contact zone with fixed movable motor . The effectiveness of the contact can be clearly identified from the holographic interferograms maps by the level of generated vibrations in the fixed motor.(see fig. 7)

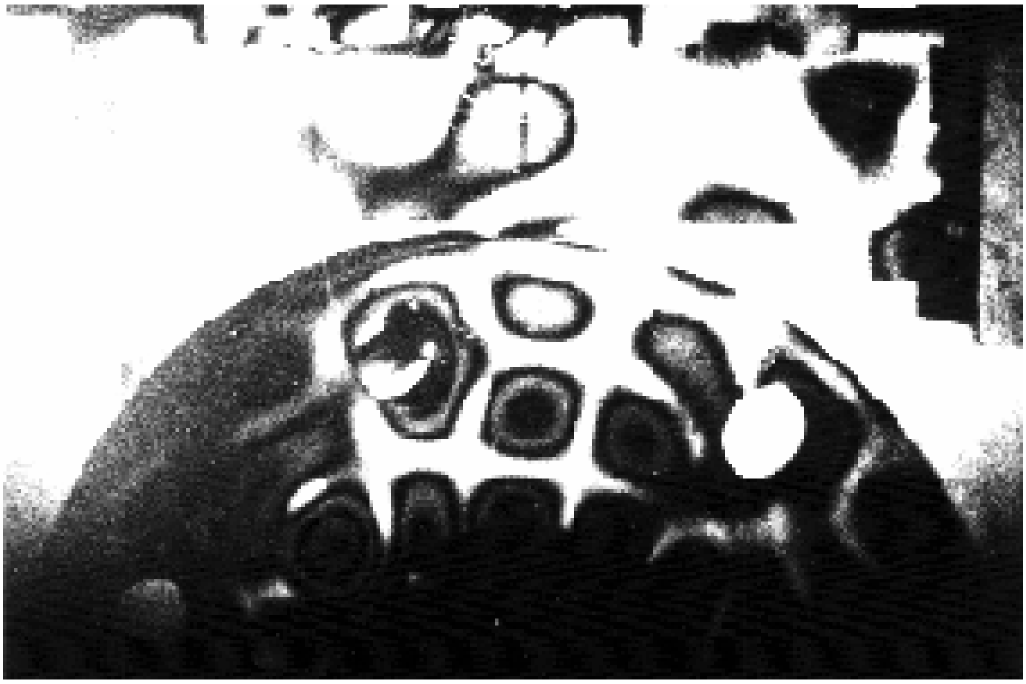


Fig.7. **Holographic interferograms of piezoelectric beam**

Analysis of mechanism of the rollomight type

In order to ensure the qualitative functioning of the mechanisms of the rollomight type the following parameters are to be controlled: the uniformity of tape tension, the distribution of the deformations of the tape in the region of contact with the roller, the quality of roller production, the vibrational processes of the tape itself in the mechanism of the rollomight type [17].

In fig. 8 the holographic interferograms of the tape in the mechanism of the rollomight type are presented which enable to judge about the quality of its tension. For this purpose when recording the holographic interferograms the tape was being excited in the normal direction. The holographic interferograms were recorded by using the optical scheme for recording the time averaged holograms of the tape (fig. 8) As the magnetic tape is being excited the amplitude of vibrations in those regions of the tape where the tension is smaller will be larger. The existance of such zones and their distribution on the surface of the tape give the qualitative view of its tension.

An important subject also is the investigation of the qualitative view of the deformations of the tape on the rotating directing rollers. The holographic interferograms were recorded by using the pulse laser of rubin by the method of paired pulses. In fig. 9 the holographic interferograms of the tape on the turning around roller from three directions of observation are presented. The angles of observation Q_2 correspond to 15^0, 30^0, 45^0. The tape tension is equal to 4N.

The control of the production quality of the rollers of the mechanisms of the rollomight type ensures the uniformity of the tape tension, in the mechanism of the rollomight type, enables to avoid the plastic deformations of the tape which occurs because of the defects of the directing rollers. The control is performed through the tape. In the places of roller defects on the holographic interferogram of the tape in the region of contact the excitation zones are observed. In fig. 10 the holographic holograms are shown on which the excitation zones that arise because of the defects of the rotating rollers are observed.

The obtaining of holographic interferograms enables to optimize the working regimes of the mechanisms of the rollomight type, to obtain supplementary data with the help of which it is possible to develop the design of devices by ensuring its dynamical precision.

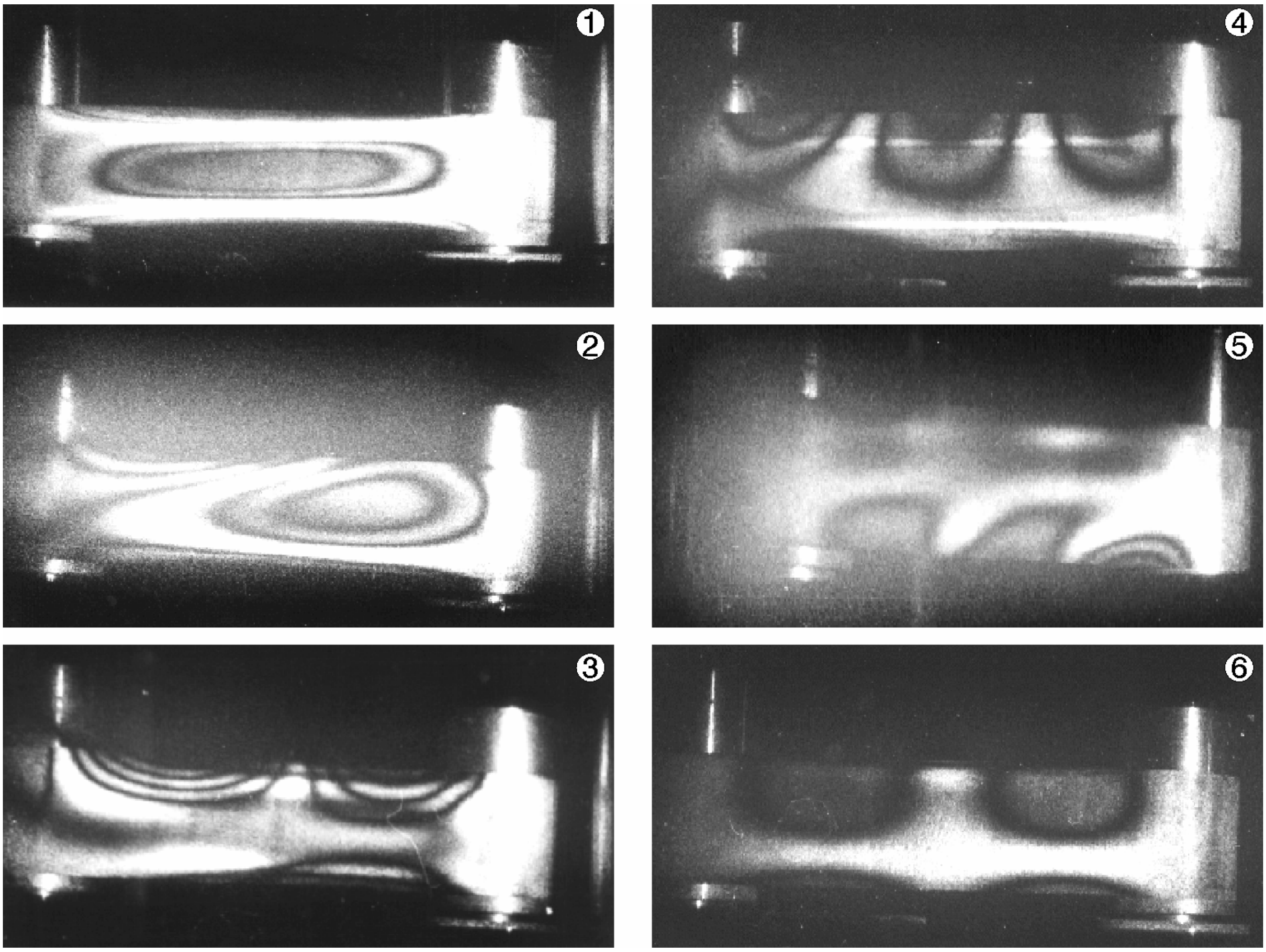


Fig. 8. **The holograms of the tape vibrations of the mechanism of the rollomight type. (1) - f=220Hz; (2) - f=250Hz; (3) - f=320Hz; (4) - f=500Hz; (5) - f=600Hz; (6) - f=420Hz.**

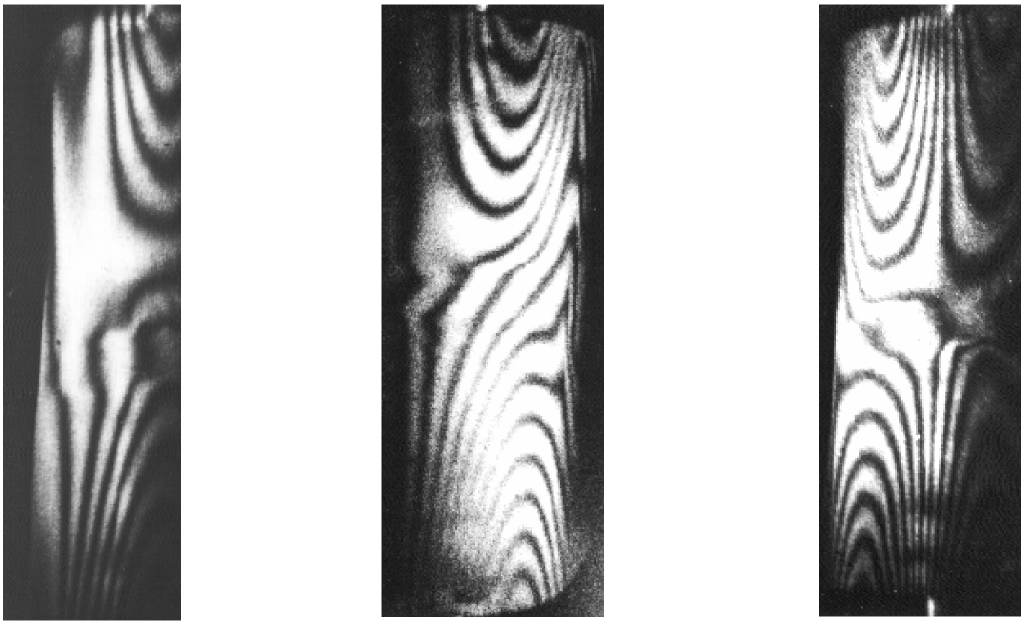


Fig. 9. **The holographic interferograms of the deformations of the tape on the rotating directing roller**

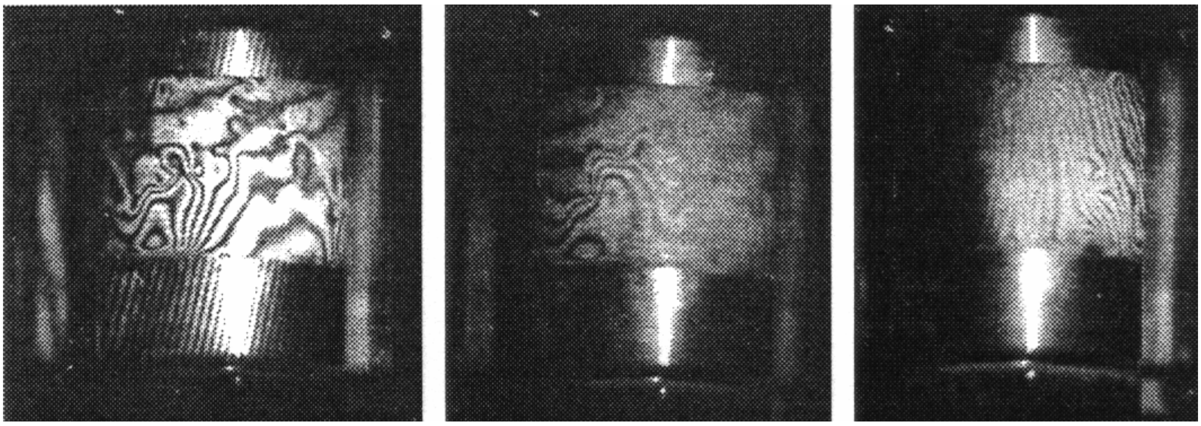


Fig. 10. **The holographic interferograms of the tape on the roller**

Investigation of hard disc

Time average and double pulse laser holographic interferometry analysis methods are applied for investigation of hard disk dynamics. The influence of temperature variations to the dynamics of the system was investigated separately due to sensitive relation between the parameters of compact disk and its temperature.

1. Investigation of the reaction of hard disk at different excitation and operating regimes of motion in fig.11 (1), (2), (3), (4), (5).

2. The analysis of the dynamics of hard disk containment at different modes of motion in fig. 11 (6), (7), (8), (9), (10).

3. The analysis of the deformations of hard disk reading head in fig.11 (11), (12), (13), (14).

The performed optimisation enabled to select the optimal construction and regimes of motion for CD driver. Holographic pattern anomalities in figures (1) and (2) in fig.11 show that the surface of hard disk is impacted with non-uniform dynamic stress. Numerous experiments had enables the best selection of fixing system properties and geometry. The successive experimental results are presented in figures (3), (4), (5) and (6) in fig. 11, were interferographic band pattern in figure (6) from Fig.11 show the best possible results. The dynamical surface deformations are analysed at different lighting and viewing angles, as it was important to investigate the spatial deformation structure. The performed analysis confirmed that the hard disk fixing construction design was optimal for the specified dynamic deformation zone.

The second task in the optimisation of the whole CD system was the analysis of the containment of the drive. It is very important for the operating characteristics of the system that the containment would not bear the torsional stress due to the changing temperatures. Such deformations can be very harmful for the dynamics of reading head and precise positioning of the head. The pattern of holographic interference bands in figures (7) and (8) in Fig.11 show the non-uniform distribution of stress originated by temperature fluctuations.

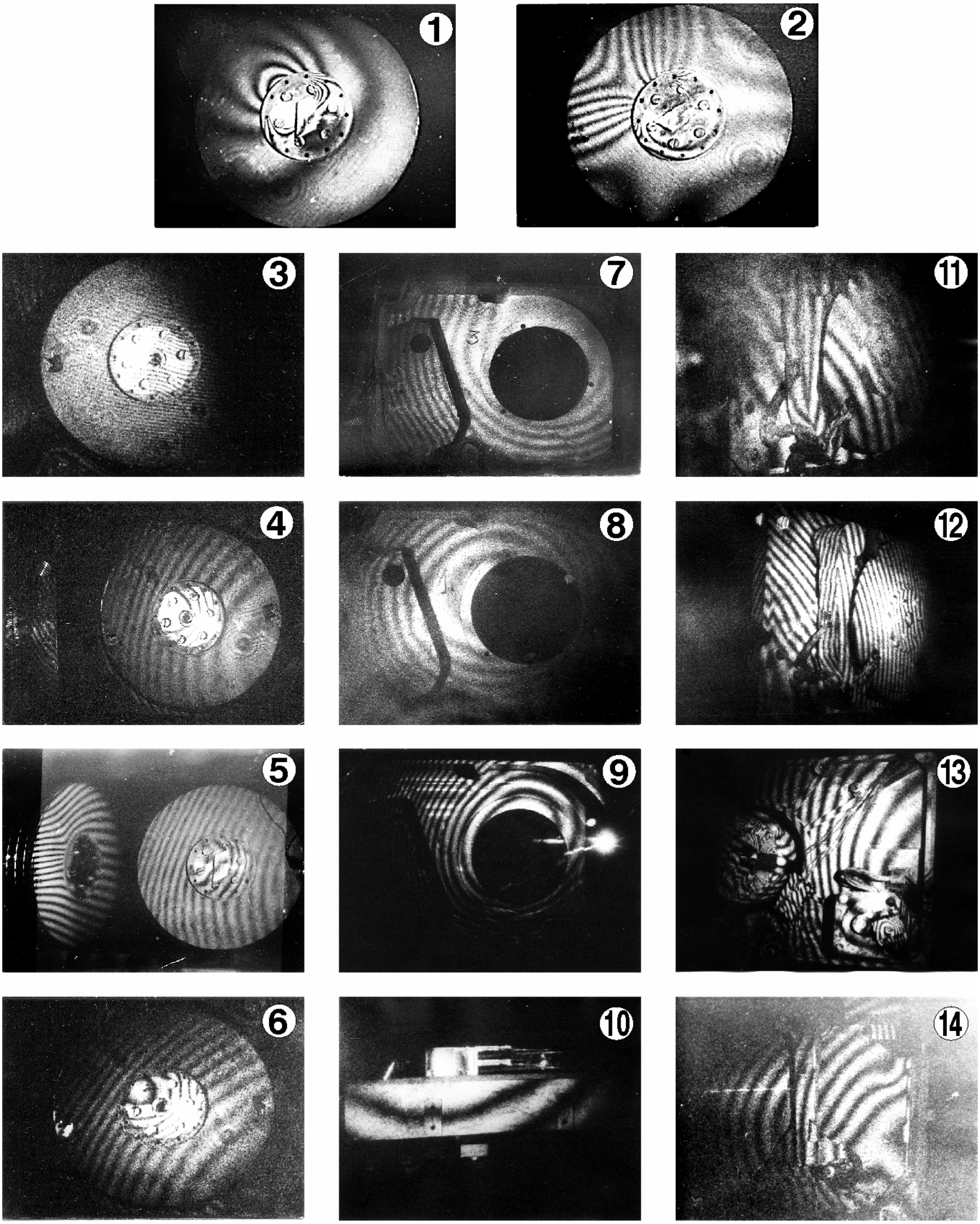


Fig. 11. **Holographic interferogram of hard disc and his elements**

Numerous experimental investigations enables finding best possible chemical composition of steel and geometrical form of the containment which is less possible impacted by stress impacts originated from changing temperatures in different parts of the system. Figures (9) and (10) in fig.11 confirm the best solution from the point of view of temperature fluctuations.

The last stage of optimisation was related to the optimisation of the reading head dynamics. Figures (11), (12), (13), (14) from fig.11 show the band pattern on the reading head surface. The anomalities in figures (11), (13) and (14) in fig. 11 show that the dynamic system reading head - containment is not harmonised. The best head fixing position in the respect of dynamic deformations is found in figure11 (12).

Laser holographic interference analysis proves to be the effective and powerful tool in optimization of dynamic characteristics of even such complex precision dynamical systems as hard disk drives.

Vibro pressing of bearings

Vibro pressing is a modern advanced technology used for precision assembly of bearings. Nevertheless, the incorrect force application may damage the structure under assembly. Even worse may happen when the assembles system may pass quality test successful, but the problems may develop in the exploitation of the system. Many of these problems could be eliminated if the pressing stage would be appropriately controlled.

Different control methods are used for the monitoring of vibro pressing of bearings. Laser holographic interference analysis system proved to be very effective for the optimisation of the working conditions of the system. Figures (1), (2), (3), (4) in fig.12 present the analysed system in operating conditions from different viewing and lighting angles. That enabled to figure out the spatial character of system surface deformations taking place in the pressed bearing structure.

Anomalities in figures (5), (6), (7), (8) in fig. 12 prove that the dynamic mode of operation is not optimal - the pressing force is not uniformly distributed around the surface of the assembled bearing.

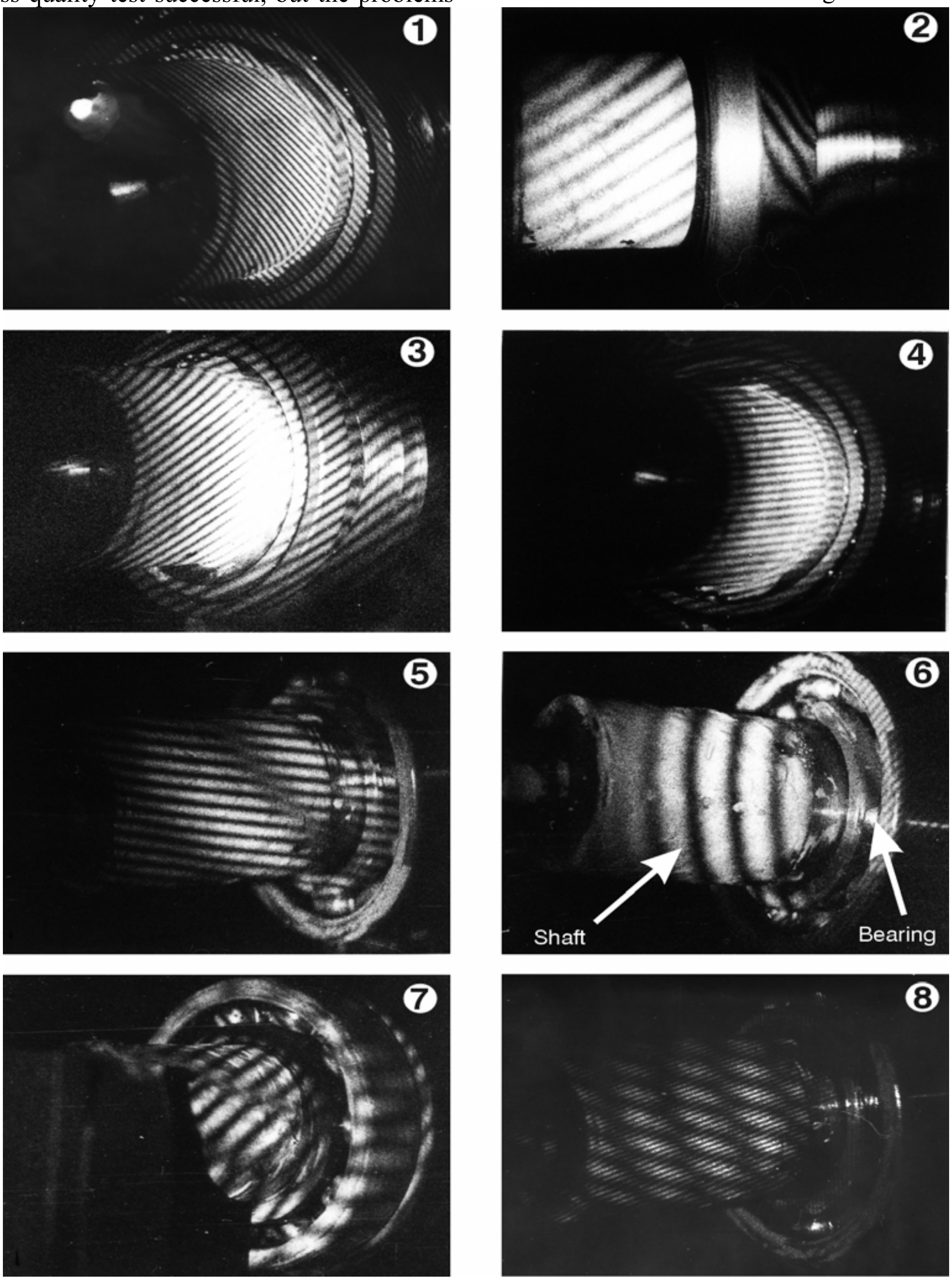


Fig. 12. **Holographic interferogram of proccess vibropressing bearing**

More important is that the incorrect pressing force can lead to impacts and rough force fluctuations during the assembly. It is very important to select the needed force and vibration frequency used in the system. Figures (3) and (4) in fig.12 show the best regime of operation - the bands are distributed uniformly and prove that the affected force will effectively assemble the bearing. The applied laser interference holographic investigation methodology proved that it is a powerful technique for the analysis and optimisation of complex system dynamics.

Investigation elements and system of adaptives optics

Mirrors of adaptive optics system are extremely precision object in the sense that the amplitudes of surface deformations reach the level of only few microns.

If vibration pressing system for the assembly of bearings, compact disk drive, or other similar precision systems could be analysed using also other methods, the adaptive optical mirrors perhaps could not be analysed by other means.

Figures (1), (2), (3) in fig.13 show general view of the mirror surface when the control signal is applied to the pjezo drivers feeding elements controlling the deformation of mirror. In all three figures the distribution of bands in not uniform, defected zones can be easily located.

Further investigation of the control system reaction enabled finding the best location of control elements and correct relative placement of reflecting mirror. Figures (1) – (6) in fig.14 show uniform and qualitative surface deformations on the surface of the whole mirror.

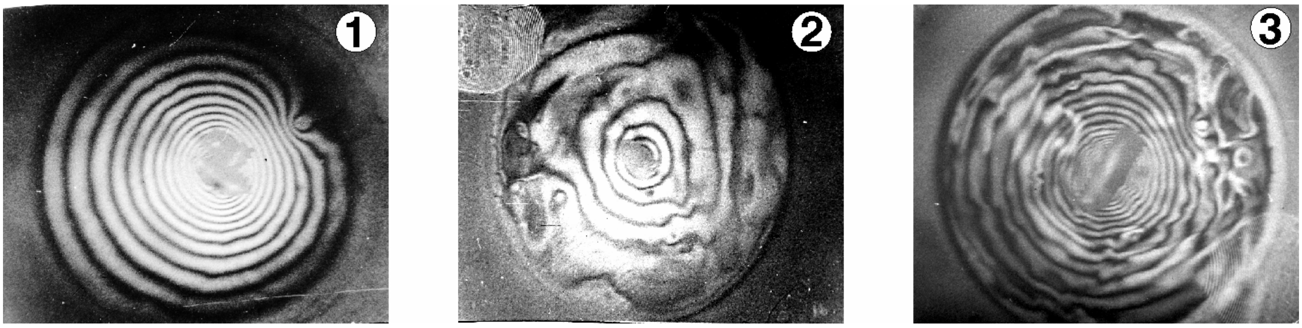


Fig. 13. **Mirror of laser beam control**

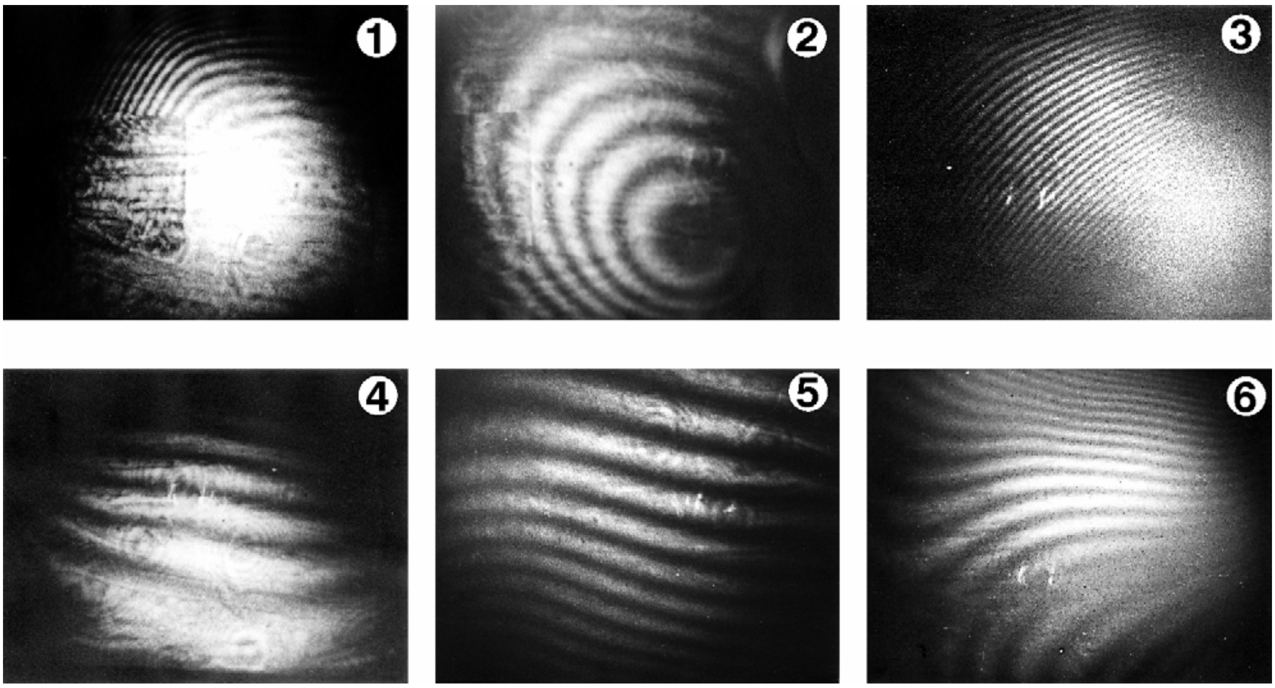


Fig. 14. **Surface deformations on the surface of the whole mirror**

Vibrationary director

The invention [18] is related to machine tool building science, particularly to directivity joint design area. The idea of invention is in the formation of air pillow between the movable and motionless parts of the system (see Fig. 15, Fig. 16).

Vibro-conveying system consists from movable part 1, motionless part 2, pjezoceramic elements 3, foundation elements 4, basic floor 5, grooving 6. The natural eigenforms of pjezoelectric elements 3 and foundation element 4 are selected in a way that the modes of longitudinal and transverse oscillations coincide.

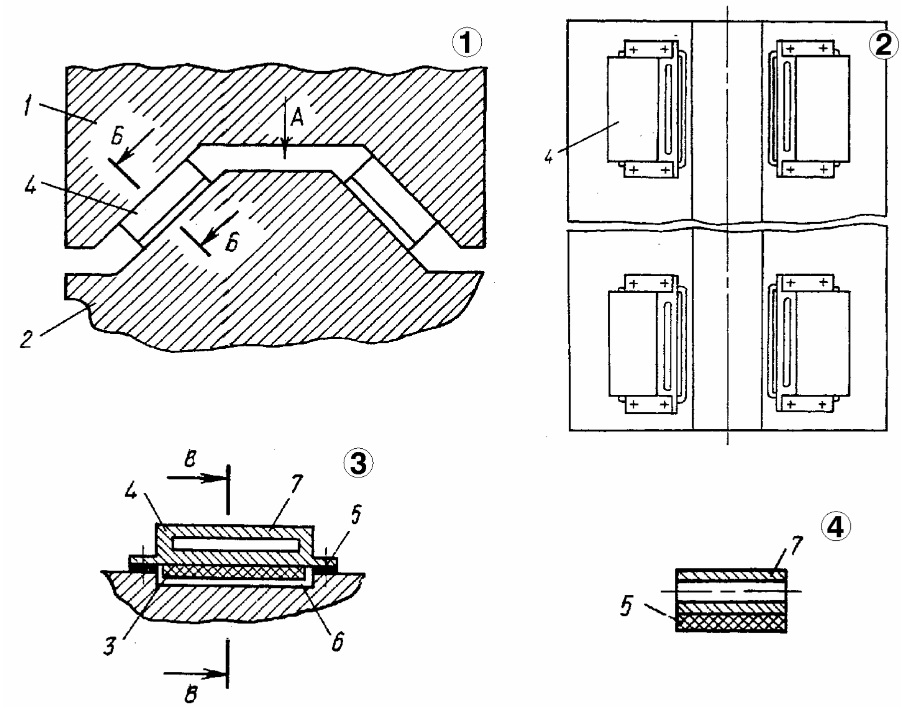


Fig. 15**. Construction of vibrationary director. (1) - vibro-conveying guideline; (2) - projection A; (3) - section B-B; (4) - section B-B**

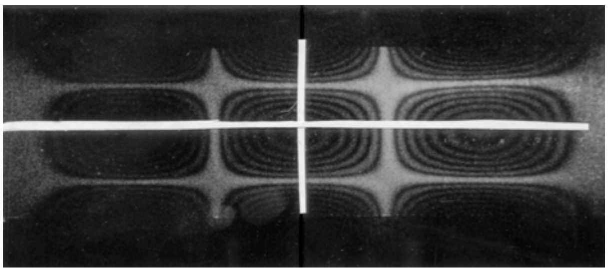


Fig. 16. **Holographic interferogram of the surface vibro director**

The movable part 1 is located on the working surface 7 of foundation elements 4.

The principle of operation of the system is based on the formation of air pillow between the working surface and the transporting organ when the pjezoelectric elements start operating and generate vibrations. The resonant frequency of the system is mostly appropriate for the application as the effectiveness of transportation is highest. The air pillow decreases the friction forces and the system operation turns to be more effective. When the forced vibrations are switched off, the movable element rests on the surface of foundation motionlessly.

Electro-hydraulic amplifier

The idea of the invention [19] is to decrease the power consumption of the system (see fig. 17, fig. 18). Therefore, electromechanical actuator is implemented in the form of piezoceramic concentrator which perform the function of throttles. Piezoceramic concentrators are produced from five pjezoceramic elements and are isolated by acoustic isolation material. The design of the system is constructed in the way that vibration concentrators may perform motion in the radial direction. The operation of all vibro-actuators generate a propagating wave which is running in the opposite way that the direction of the liquid flow. Thus the hydro resistance of throttles is increased. Also the turbulence of the flow is increased due to the resonant frequency of the actuator.

Vibrational dispergator

Vibrational dispergator [20] consists from concentrically located cylinder shape ultrasound processing chambers. The cylindrical walls of the chambers (see fig. 23, fig. 24.) are formed by piezoelectric actuators fed by the power sources of resonance and impulse constant current. When the liquid is fed into the ultrasound processing chambers and the piezo-actuators start vibrate at their resonance frequencies, radial standing waves are generated around every actuator. The resonance frequency for the actuators is different and depends from the radius of actuators. Thus the flowing liquid is processed with higher frequency ultrasound every time it passes through

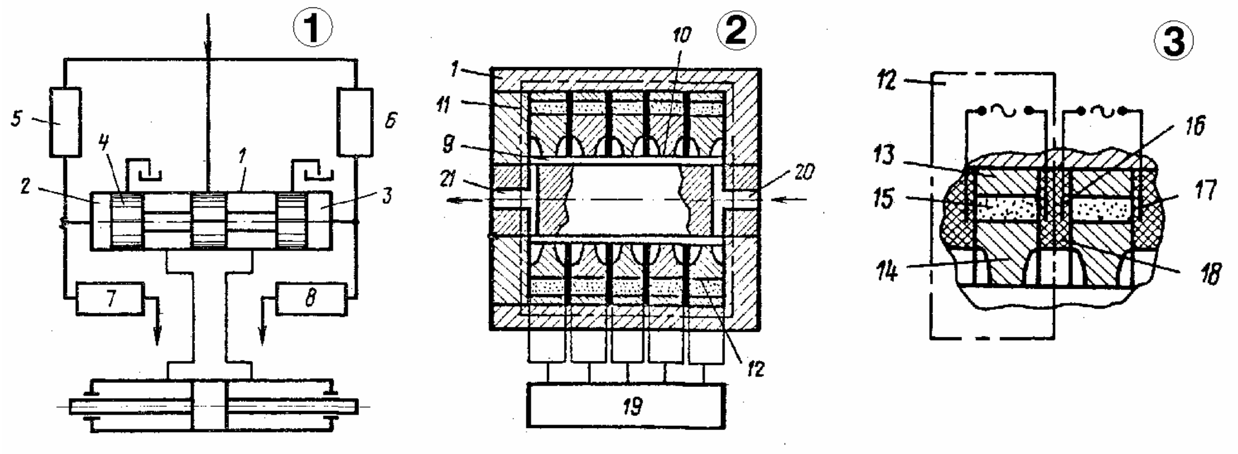


Fig. 17. **Construction of the electro-hydraulic amplifier. 1. Frame; 2. - 3. Torsional chambers; 5. - 8. Throttles; 9. Electromechanical actuator; 10. Piezo-ceramic actuator; 11. Piezo-ceramic element; 12. Vibration concentrators; 13. - 14. Steel rings; 15. Piezo - ceramic ring; 16. – 17. – electrodes; 18. - Isolation material; 19. - sensor contact; 20. - 21.- input and output hydro liquid lines**

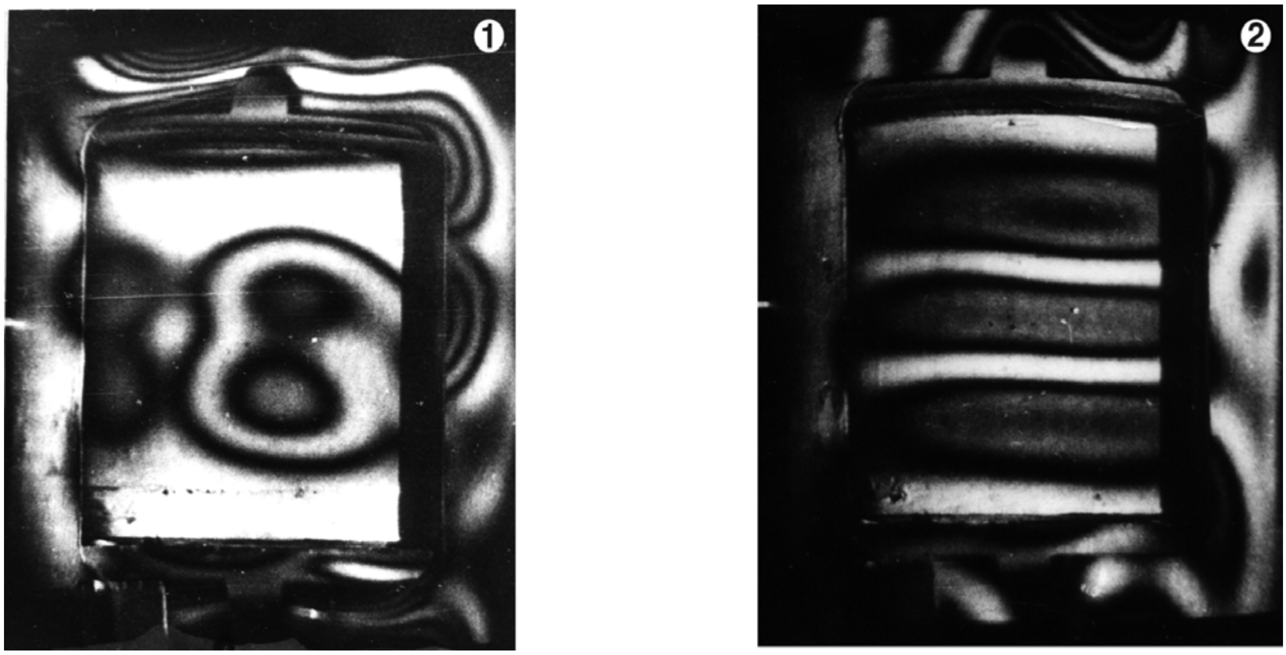


Fig. .18. **Holographic interferogram of the electro-hydraulic amplifier**

the next processing ring. At the same time the high peak constant current actuators radiate high energy impulses to the processed liquid. Thus the whole process of dispergation turns to be more effective. The regulation of the quality of dispergation may be performed by the control of the level of constant voltage peak level. It was proven experimentally that the effectiveness of the process is increased 3 times at the following parameters.

Holographic interferometry was used for the optimization of construction and design mechanism presented in [12].

Conclusions

The application of laser interferometry holograms enables the optimization of the construction of vibromotors. It is relatively easy and very effective mean for vibromotor characteristics investigation. In this case the set of vibromotors analyzed characteristics is much broader that only direct characteristics of motion produced by ordinary tests. Moreover, such kind of analysis does give guidelines not only for optimization of vibromotors, but together with analytical and numerical analysis may lead to the design of new and more sophisticated mechanisms.

The performed holographic research and the performed analysis of wave transportation systems according to the experimental data enabled to create the transportation systems of the principally new type. The experimental research of transportation systems with the use of holographic interferograms enabled to determine the reasons because of which lateral, of damped type and traveling waves are generated and this enabled to eliminate then thus enswing the dynamical stability and precision of the performance of transportation systems.

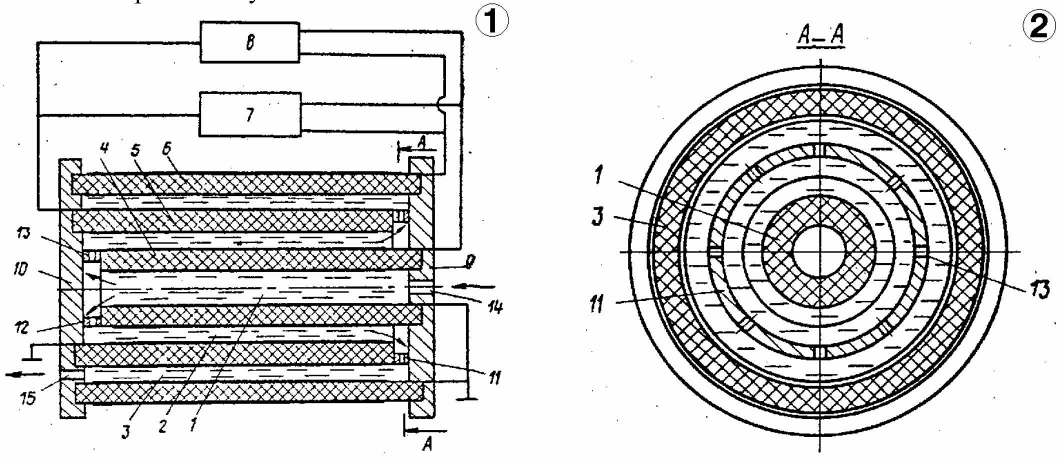


Fig. 19. **Construction of the vibrational dispergator. (1) presents longitudinal section of dispergator; (2) - section A-A. 1-3 - ultrasound processing chambers with cylindrical walls; 4-6 - piezo-electric actuators; 7 - power supply of resonance voltage; 8 - power supply of impulse 15 - liquid output connector.voltage; 9-10 - fixing rings for cylindrical walls; 11 -12 - ring type holders; 13 - radial openings in holders for liquid inflow; 14 - liquid input connector**

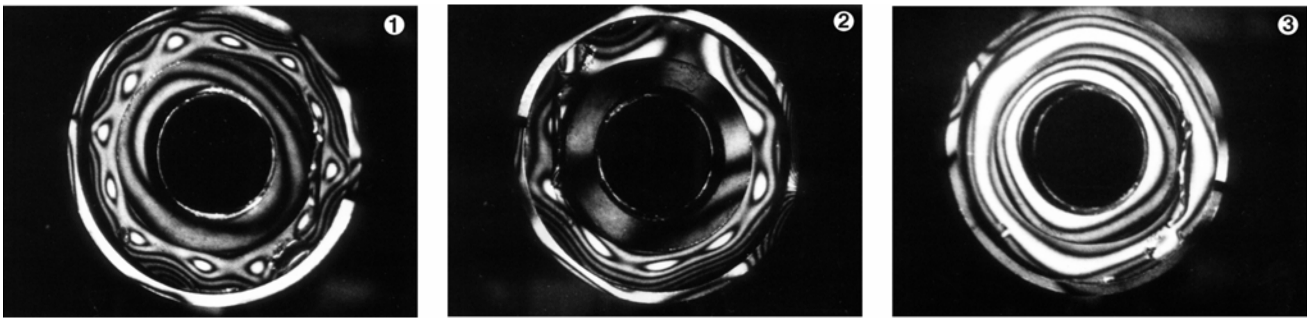


Fig. 20. **Holographic interferogram of the vibrational dispergator**

Investigation process in contacts of links in real construction by means of holographic interferometry allows to find boundary conditions of actuators and to increase energy transfer in this contact.

Laser holographic interference methodology is a powerful and effective tool for design analysis and optimization of operation of many different kind of systems. In some cases this is the only possible tool of analysis (adaptive optics mirrors), in other cases it is a good and effective tool of analysis, which in some instances exceed the possibilities of other research and monitoring methods.

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Baninių mechaninių sistemų tyrimas, optimizavimas bei konstravimas naudojant holografinės interferometrijos metodus

Reziume

Straipsnyje pristatomi holografinės interferometrijos praktinio taikymo pavyzdžiai susiję su šio metodo naudojimu tiriant, optimizuojant bei konstruojant įvairių tipų bangines mechanines sistemas, tokias kaip vibrovariklai, vibrotransportavimo mechanizmų mazgai, juostos pratraukimo mechanizmai, kompiuterių kietų diskų elementai.

Pateikti pavyzdžiai iliustruoja šių metodų taikymo privalumus lyginant juos su kitais eksperimentinio tyrimo metodais.

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