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PROBLEMS OF MECHANICS IN THE LIGHT OF RESOLUTIONS OF THE 26-TH CONGRESS OF THE COMMUNIST PARTY OF THE SOVIET UNION*

(Plenary address to the 5-th All-Union Congress on Theoretical and Applied Mechanics, Alma-Ata, 27 May 1981).

A.Iu. ISHLINSKII

"The country urgently needs the 'great science' besides solving theoretical problems, to put greater emphasis on the solution of key problems of national economy and on inventions capable of bringing truly revolutionary changes in production." L.I. Brezhnev in the Summary Report to the Central Committee of the Communist Party of the Soviet Union at the 26-th Congress, and the Party's current aims in the domain of internal and external policy. Pravda, 23 February 1981.

Mechanics, a constituent part of the 'great science', occupies one of the key positions among the sciences that directly ensure the acceleration of scientific and technical progress. It plays a leading part in the development of the basis of technology, using methods of physical research, mathematical analysis, and computation techniques.

Achievements in the field of machine and instrument manufacture, building industry, hydraulic engineering, mining and processing of ore, coal, petroleum, and gas, the development of rail and road transport, shipbuilding, and of aviation and space technology are based on a deep understanding of the laws of mechanics and on calculations that are, in turn, based on experimental data and theoretical investigations.

Each statement in the document "Fundamental Directions of Economic and Social Development of the USSR for the years 1981-1985 and in the period up to 1990", approved by the 26-th Congress of the Party, is about the specific business and work of the Soviet people. A considerable part of statements is directly related to science in general, and many are particularly relevant to mechanics.

Thus for "increasing the quality, reliability, economy, and productivity, reducing noise and vibration of machines, equipment, and other products of mechanical industry, lowering their material content and energy consumption" (**) use is to be made of the achievements of the theories of oscillations, strength and wear resistence of materials, the theories of friction and lubrication by gas and by surface-active substances, and new problems to be formulated and solved in these disciplines.

Gasdynamics and the theory of control must be fully equipped for "carrying out the design and construction of powerful highly automated gas mains of high operational reliability," while the theory of strength of materials must provide means for "mastering the production of laminated pipes for gas mains."

Not a few problems of general mechanics, aero- and hydromechanics will have to be solved in order to carry out the directive to "create some fundamentally new forms of transportation means ..." and, also, to "accelerate the introduction of new means of special continuous forms of transport, such as conveyors, pneumatic, hydraulic and other containers, particulary for the mining and chemical industries, and in the production of building materials."

It is not diffcult to indicate similar inter-relationships between all branches of mechanics and the practical business of the national economy that were given priority in the Fundamental Directions.

1. The theory of machines and mechanisms. Robots and manipulators.

A considerable importance is given in the Conference proceedings to the reduction of manual labor, and the necessity to "develop the production and ensure the wide use of automatic manipulators (industrial robots) ...." This is a wide field of application of general mechanics, of the theory of servo-mechanisms with allowance for elasticity, of ideas of robot sensitization with

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**) Fundamental Directions of the Economic and Social Development of the USSR for the years 1981-1985 and in the period up to 1990. Moscow, Politizdat, 1981. Here and subsequently extracts from that document and from L.I. Brezhnev's Summary Report to the 26-th Congress of the CPSU appear in quotation marks.

wide use of micro-computers and, if required, to design some very simple functions of the so-called artificial intelligence. The use of robots and automated equipment is particularly important in "coal extraction in pits without constant presence of people at the stope face."

The contemporary technical robot complex is an amalgam of achievements in the fields of mechanics and computation technique. Hence it is important to have a properly organised processing of the initial information from sensors to the robot microprocessor.

In the course of the current five year plan effective methods and algorithms must be developed for the control of robots, taking into account actual properties of their structures, particularly the elasticity of linkages and hinges, and the effect of working clearances. Methods of determining optimal modes of typical operations must be developed for various kinematic schemes of robots and manipulators. Considerable attention is to be given to methods and means of measuring mechanical quantities such as stresses, moments, pressures, ranges, and displacements of robots in motion, and also to sensors for the control of actuators. The methodology of modelling, including models combining simulation with the use of sample products already produced by our industry is to be developed with the aim of further improvement of the latter and acceleration of the introduction in technological production processes.

Manipulators and robots can be extensively used not only in the coal industry but, also, in other important branches of industry, for instance, in machine and instrument manufacture, electronics, power and electrical engineering.

2. **Friction and wear. Durability of machines.** The science of friction has been for many years a blank spot in mechanics. The resistance generated by the relative motion of contacting bodies depends (sometimes in a freaky manner) on a number of factors, such as surface roughness of bodies, duration of contact prior to sliding, resistance to plastic deformation, temperature, and the chemical composition of rubbing bodies, on the ambient medium, presence of lubricants and their properties, on the pressure exerted by bodies on each other, on vibration and even on irradiation. The same is true in relation to wear by friction, the main enemy of machines.

Passing to the molecular level in investigations of friction and wear, with physicochemical phenomena in the contact region of sliding bodies taken into account besides mechanical ones, enabled us to understand many aspects of this complex process and to influence it in the desired direction.

As a result, it is now possible to produce antifriction materials for plain bearings with wear and friction losses by one order lower than those of conventional materials. The opposite problem, production of materials for brakes that combine high friction properties with low wear at high temperatures, is being successfully solved.

The practical importance of research into friction and wear of materials and, particularly, of the introduction of its well proved results in machine construction cannot be overemphasized. The cost of repair of worn units of machines, machine tools, tractors, cars, pumps, and agricultural implements is several times higher than that of their manufacture, and the spare parts metal content is about one fifth of that of the complete product.

The processes taking place in ball and roller bearings are even more complex. Their study is complicated by the scatter of ball and roller dimensions, their deviation from the perfect ball, cylinder, or taper shape, and inaccuracies in the working surfaces of bearing rings. All this leads to excessive local contact stresses and subsequent flaking of surface layers of metal.

Further investigation of antifriction bearing mechanics and working out recommendations for their manufacture and use is one of the most important tasks for the machine, instrument and gyroscope industry.

3. **Complex mechanical systems. Analytical mechanics. Vibro-impact machines.** Although at present of theoretical interest, but in future of obviously practical interest is the development of new schemes for gyroscopic and other inertial equipment for various purposes. Among these are: the gyroscopic compass, the unperturbed vertical using the gravity gradient, accelerometers for measuring the angular velocity of an object, and others.

The increasing complexity of mechanical systems containing an ever higher number of solid bodies should be noted. Even the construction of error-free equations for such systems is in itself a laborious and tedious job. Computer techniques are now becoming available for constructing equations for systems with many degrees of freedom.

Investigations of the unsteady motion of a vibro-impact systems were earlier carried out by the unwieldy method of the so-called fitting of solutions to time intervals between impacts. Recently, a special procedure for eliminating one-sided constraints enabled us to consider the motion of such systems in an infinite time interval, and to solve new and important problems of this branch of engineering.

4. Mechanics of solids. Strength and stability. Optimal design of building structures. Considerable attention is paid in the decisions of the 26-th Congress of the CPSU to the building industry and its radical improvement. As pointed out in the Fundamental Directions, it is necessary to "give priority to the development of articles that would reduce costs, and metal and labor contents of buildings, reduce the weight of buildings and structures, and increase their thermal insulation," and also to "build-up the output of modern reinforced concrete, steel, and wood bonded structures," and utilize ashes, slag, mining industry waste, fiberglass, and non-metallic materials.

An important part in the solution of these problems is played by the mechanics of structures, the theory of their stressing, the theory of elasticity and plasticity, of creep and aging, and mechanics and plates and shells. One of the main problems here is the determination of the life span of the load carrying capacity of modern building materials and structures, taking into account the accumulation of damage, development of cracks, and in many instances of seismic loads and low temperature effects. Further development is required of methods of project optimization, stability determination with allowance for geological factors, and of the calculation of structures subjected to the dynamic effects of large machines, traffic, wind, and sea swell and, also, of industrial explosions.

Considerable difficulties are encountered in the erection of large nonstandard structures such as covered stadia. Determination of optimum erection technology necessitates the solution of a number of problems of the applied theory of elasticity.

At present the process of building erection is, as a rule, one of continuous build-up of its structure. In the case of concrete (and also of ferroconcrete, wood, and plastics) this means that the age of materials and various parts of the structure is different. This makes it necessary to take into account the laws of the creep theory, particularly of unevenly aging materials. The same problems arise in the case of crystal growth, phase transformations, and growth of bodies.

Finally, methods must be developed for calculating the so-called light structure whose bulk consists of polymers. Mechanical properties of the latter are complex and depend on many factors, particularly on temperature and vibrations. The structure of polymers is heterogeneous, and they are prone to damage accumulation in the course of time. All this needs theoretical and experimental research.

5. The theory of material fracture. Reliability of large-scale structures. Forecasting natural phenomena. Many branches of industry require the development of reliable methods of calculating the efficiency and durability of contemporary large-scale structures, pressure vessels, pipelines, turbines and hydraulic power plants, power generating plant of atomic power stations, ships, aircraft and helicopters.

Fracture is caused by a number of factors such as the formation and development of cracks, including fatigue cracks, the simultaneous action of load and corrosion inducing media, including radiation, and in some cases the deterioration of viscous and plastic properties at comparatively low stresses.

The study of various fracture mechanisms and the construction of reasonably satisfactory models of that phenomenon is the subject of the so-called fracture mechanics which now becomes also the basis for the development of composites and alloys of higher crack resistance.

Laminated pipes are resistant to the formation of long longitudinal cracks that result in serious breakdowns. The crack 'traps' proposed by B.E. Paton, which inhibit crack propagation, are an excellent example of the engineering approach to combating this dangerous phenomenon.

Methods of fracture mechanics led to new approaches to the analysis of various natural phenomena such as earthquakes, formation of tsunamis, mining shocks, and sudden eruptions in pits. It has become possible to forecast such phenomena, and even to avert them.

Of practical interest are the aspects of the theory of crack propagation under conditions of high-speed load application. They appeared recently in connection with experiments on cleavage strength.

6. Crack development under cyclic loading. Relation between fatigue strength of specimens and of actual machines. Disastrous failures of aircraft, helicopters and sometimes of ships, breakages of machines and their major units is most often due to material fatigue, another blank spot of mechanics.

It was established that the cause of fatigue failure is the gradual development of internal cracks in the material owing to alternating stresses present in the normal operation of machines and to accompanying vibrations.

It is now possible to assert that the crack development process consists of the following three stages (Fig.1). The preliminary stage which in a given material can develop in several ways, depending on the technology of the specimen or actual component preparation; the basic stage in which a universal relation of the power type exists between the rate of crack length increase and the difference between the maximum and minimum values of the stress intensity coefficient near its tips, followed by the avalanche-type final stage which, like the initial one, can develop in various ways.

The indicated universal relation contains two parameters that depend on the mechanical properties of the material and on the shape and size of the test specimen of the actual component. The respective functional relationships have not yet been established with the required reliability. This is now, possibly the main problem of the theory of fatigue, which is of considerable practical importance. Its solution will enable us to make reliable assessments of the fatigue strength of actual machines and structures on the basis of test data obtained on small laboratory specimens.

7. The theory of plasticity and forming by pressure. In the case of combined stresses and large deformations the theory of plasticity must provide and develop the basic conditions for the "substitution of economic methods of forming components for the technological processes based on the cutting of metals." Scientists in this domain of mechanics must help industry to "produce and introduce in machine manufacturing enterprises component-rolling mills that would ensure minimum waste in the metal-rolling process."

Combined loading of material beyond the elasticity limit occurs in many technological processes such as forging, drawing, stamping, and in engineering structures and machines during their work. The strain theory of plasticity and of plastic flow is not always applicable here. Vast experimental data accumulated about combined loading show plastic deformation to be the result of slip of small material particles relative to each other over the totality of variously oriented planes.

Such view of the essence of plastic deformation led to the formulation of the new, so-called, semi-microscopic theory of plasticity in which it is necessary to consider, besides the clearly apparent plastic deformation and the well-known elastic unloading of the material, also the intermediate processes of the peculiar incomplete plasticity (Fig.2). It appeared that in calculations, which are generally in good agreement with experiments, it is sufficient

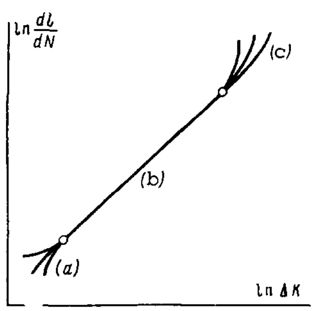

Fig.1

Fig.1. Dependence of the rate of increase of crack dimensions due to fatigue on the alternating load parameter. Crack behavior in the initial (a) and fracture (c) stages depends on the specimen preparation technology. The equation of the universal part (b) of the curve is defined by two parameters. Here

$$dl/dN = C\,(\Delta K)^m,\ \Delta K = K_{max} - K_{min},\ [K] = \text{kg}\cdot\text{cm}^{-3/2}$$

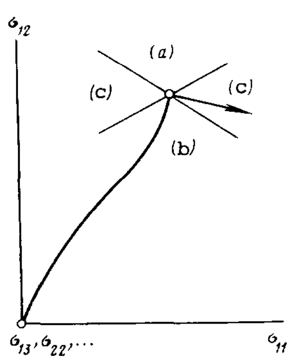

Fig.2

Fig.2. The semi-microscopic theory of plasticity. Region of the stress state change of direction in which the following takes place: (a) additional plastic load, (b) elastic spring-back, and (c) partial (incomplete) plastic deformation.

to introduce in the equations of perfect plastic deformation, in addition to the elastic limit, only one more constant.

Plastic deformation is accompanied by a change of structure of the material. The importance of the semi-microscopic approach in the theory of combined plastic loading is in that it enables us to explain these structural changes. For this appropriate experiments with respective theoretical calculations must be carried out.

8. The mechanics of ice. Transport, building, and petroleum and gas extraction in the extreme North. A number of new problems of hydrodynamics and of mechanics of solids is to be considered in connection with the utilization of natural resources of the extreme North and of the Arctic shelf. This comprises the assurance of drilling and extraction of petroleum and gas under conditions of permafrost, and the study of interaction between engineering structures and the mighty ice blanket.

The study of mechanical and physical properties of ice and of its interaction with icebreakers is not an unimportant part of the problem of "Ensuring a round-the-year navigation in the Western part of the North Sea lane and a regular supply of goods to regions of the extreme North and of the Far East."

To achieve this one must be able to break-up ice fields with minimal losses, and aim at maximum reduction of ice resistance by mechanical means. On the other hand, when ice is used as a structural material for airfields, temporary bridges, and drill rig construction, it is important to improve the ice strength properties; the latter can be achieved by the introduction of additives (particularly polymers) or reinforcements (wood, plastic, or metal). Knowledge of ice properties is also required in the study of glaciers and of ice field pressure on structures and drifting ships.

To aim at constructing a single model for defining the behavior of ice under any conditions is hardly worthwhile. It is more effective to select in specific cases a particular model that would define the elastic, plastic, and creep, or even more complex behavior in a given variation range of age, temperature, pressure, and load application. The unequal resistance of ice to tension and compression, its fracture in the process of deformation, and its anisotropy and inhomogeneity must also be taken into account.

9. Subterranean physicochemical hydrodynamics. The theory of filtration. Petroleum extraction on land and in the sea. Mechanical problems are of great importance in the petroleum industry in relation to the aims set out in the Fundamental Directions: "to increase petroleum extraction from oil-bearing formations by extensive use of new methods of working them. Introduce modern methods of petroleum extraction by gas pressure, high-capacity submerged electric pumps, and improve the technology of mining high-viscosity and bitumenous oils." This requires the development of new paths of research in the domain of subterranean physicochemical mechanics and of the theory of filtration for determining optimal location of bore-holes and their operation mode, the application of heat and active chemical reagents to oil-bearing formations, and the reduction of oil viscosity by underground fires. It may be useful to recall that even now the yield of oil-bearing formations is noticeably less than half of its petroleum content. Hence attention must be concentrated on the theoretical development of methods of increasing the yield of such formations. It appears that the majority of existing methods may, in spite of their variety, be represented by the single model of petroleum displacement by a water solution of an active reagent which alters the hydrodynamic properties of both water and petroleum. That model made possible the establishment of the minimum volume of input information required for sound specific technological calculations.

It is interesting to note that the basic results in this field were obtained, as at one time in the nonlinear theory of filtration, using the strict hydrodynamic approach and the mathematical apparatus developed in gasdynamics.

The actual conditions of petroleum and gas extraction from the off-shore shelf and from the sea bed pose new and difficult problems of mechanics. The huge platforms costing hundreds of millions of rubles have to operate under extreme conditions, maintaining their absolute stability, strength and reliability. This requires the ability to calculate the maximum loads imposed by surface and internal ocean waves, determine stresses induced by these in the material, and to estimate the structure stability under such adverse conditions. It is also essential to know the peculiarities of behavior of platform actuators under conditions of sea swell and liquid stratification. All these are problems of hydro- and structural mechanics and of the theory of strength of materials.

10. The unsolved problems of mechanics. Turbulence and strange attractors. The Fundamental Directions stress the necessity to "ensure the priority development of fundamental research and to increase the effectiveness of applied research." This in relation to mechanics implies the necessity of persistent work of scientists on the so far unresolved problems of a specific, as well of a fairly general character. The latter comprise turbulence, friction, fatigue, plasticity, fracture, and some others, including problems of seismology, meteorology, and hydrodynamics of the ocean. Let discuss some of them.

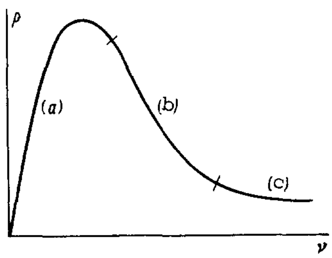

Fig.3

Fig.3 The amplitude-frequency characteristic of turbulence pulsations: (a) the low frequency section, (b) the section of curve conforming to Kolmogorov's equations, and (c) the high-frequency section 'truncated' by polymer additions.

Turbulence is an already hundred years old blank spot of mechanics. Many attempts were made at explaining, for instance, why in pipes with flow at the critical Reynolds number, usually close to 2300 but in some cases reaching several tens and even hundreds of thousands, a 'rigid', i.e. sudden onset of turbulence takes place in the flow which up to then was laminar? And why the return to the laminar mode in the case of 'late' turbulence onset appears to be sluggish and occurs at Reynolds numbers noticeably lower than the critical? What is the cause of the specific form of the particle velocity pulsation spectrum when the fluid motion is turbulent (Fig.3)? Why are its higher frequencies 'truncated' by the addition of quite small quantities of long-chain polymers, and why is it accompanied by a sharp decrease of the drag of bodies moving in the fluid? Is it possible to construct a theoretical model of two- not three-dimensional turbulent flow? What is the explanation of the peculiar frequency spectrum of the Couette flow at stability loss in the case of different angular velocities of cylinders between which the fluid is contained? Why does the degree of roughness of solid boundaries such as pipe walls or aircraft wings affect turbulence onset in a stream? This part of mechanics contains a number of such puzzles.

A new approach to the problem of turbulence generation is now taking shape. Mathematically it is related to the theory of the so-called strange attractors, at present under development, which is in essence related to singularities of the behavior of solutions of certain systems of nonlinear differential equations. When the system is of second order, its solution is represented by the motion of a point in the phase plane. The problem reduces to the analysis of integral curve behavior near singular points and the derivation of periodic solutions in the form of limit cycles, and the determination of their stability. All this has been known for a fairly long time.

However, even in the case of the system of three first order equations

$$\frac{dx}{dt} = -\alpha x - \alpha y, \quad \frac{dy}{dt} = -xz + \lambda x - y, \quad \frac{dz}{dt} = xy - \beta z$$

similar to the dynamic Euler's equations of a solid body motion around a fixed point

$$A\frac{dp}{dt} = -(C - B)qr, \quad B\frac{dq}{dt} = (C - A)rp, \quad C\frac{dr}{dt} = -(B - A)pq$$

and even to a greater extent, in the case of higher order systems, the integral curves, although still attracted to some limit set, behave in a number of cases in a random manner. In spite of the clearly determinate statement of the problem, the solution has features of a random process. Properties of the solution may very abruptly, depending on some important parameter appearing in the coefficients of equations of the system. Precisely such systems are obtained in attempts at approximating by Galerkin's method the criteria of turbulence onset in a number of specific viscous fluid flows.

It is hoped that the method of finite elements may hasten the progress in the research into turbulence. Of interest, is also the proposal to calculate the turbulent flow as the motion of some continuous medium whose tensors of stresses and strain rate are linked by nonlinear relations.

11. Solitary waves. Connection with theoretical physics.

The nonlinear Korteweg—de Vries differential equation in partial derivatives

$$\frac{\partial v}{\partial t} + v\frac{\partial v}{\partial x} + \beta\frac{\partial^3 v}{\partial x^3} = 0$$

proposed in the last century, plays an important part in the analysis of waves on the surface of a heavy fluid.

In spite of its extreme simplicity - it contains only three terms and a single parameter - it enables us to define a number of surprising phenomena related to the origin, development, and propagation of solitary waves on the surface and in the depth of the ocean.

In accordance with that equation, a plane-parallel perturbation of a part of an infinite pool surface must propagate at a velocity that depends on the rise of fluid in the perturbation middle part, forming a solitary wave, the soliton. When two solitons move at different velocities, one of them appears to pass through the other virtually unchanged (Fig.4), and this with the explicity nonlinear character of the Korteweg—de Vries equation! It should be pointed out that the solitary wave theory was considered in one of M.A. Lavrent'ev publications.

The Burgers equation

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} - \nu\frac{\partial^2 u}{\partial x^2} = 0$$

appears in the theory of filtration. It differs from the Korteweg—de Vries equation only by the order of the higher derivative. The Soviet scientist V.A. Florin was successful in finding an interesting transformation of that nonlinear equation into a linear one. This was later done by American scientists. Attempts to find a similar transform for the Korteweg—de Vries equation led to the discovery of a profound association between it and one of the basic equations of wave mechanics. Highly interesting unexpected spectral properties of the Korteweg—de Vries equations were also revealed. Such ties between mechanics proper and contemporary theoretical physics can be detected also in other cases.

12. Mechanics and physics. Gyroscope engineering. Inertial navigation.

Solutions of many problems of mechanics, particularly of those directly related to practice, involves, as a rule, the use of all of its branches together with physics, chemistry, and computational mathematics.

Thus, the creation and improvement of ultra-accurate gyroscopes requires the solution of a number of problems of electrostatics and electrodynamics, of the electromagnetic field, of

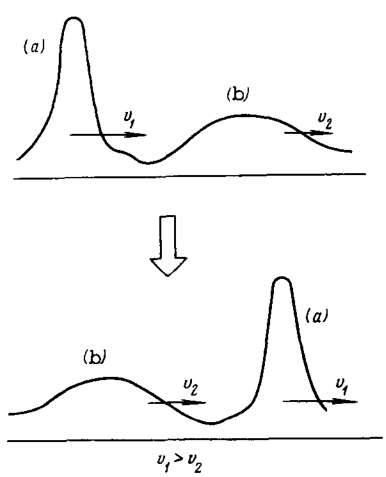

Fig.4

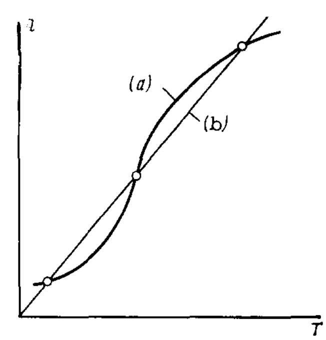

Fig.5

Fig.4. The soliton (a) a solitary wave travelling at a higher velocity then the soliton (b), and overtaking the latter almost without changing its form.

Fig.5. The dependence of heat release (a) and losses (b) on the temperature of the chemical reactor. The middle point of intersection of curves corresponds to the optimal steady state mode which is unstable.

the technology of multiphase alternating current, mangnetic hysteresis, heat conduction, of the nucleus spin properties, of coherent laser radiation and, also, hydro- and gasdynamics, the theory of elasticity, elastic after-effect and stress relaxation, and of the theory of resonance phenomena.

A theoretical limit of the attainable accuracy of the free gyroscope is imposed by elasticity of the ball bearing support. The limit is due to the variation of the bearing radial rigidity depending on the orientation of its balls relative to the load action line. Any significant increase of accuracy of the free gyroscope and other present-day sensitive elements of inertial systems is now hindered also by thermal noise. Control of the latter requires the application of cryogenic techniques, and of superfluidity and super conductivity effects.

Navigation of sea-going ships and air- and spacecraft is to a large extent based on inertial systems in the form of complicated electromechanical complexes with analog and discrete computing equipment and servomechanisms.

Transient processes and the accumulation of errors in such systems are determined by the presence of all kinds of perturbations, determinate as well as random. The problem of taking them into account and the selection of optimal correction of the effect on the inertial system of extraneous information about the object motion is difficult. It is at present solved by means of mathematical simulation. In real time it is possible to include in the model complex individual already manufactured units of the inertial system, which enables us to study peculiarities of their behavior at transitory modes, and to assess the quality of their manufacture.

13. Mechanics of laser technology. Improvement of mechanical properties of materials by the action of electric current pulses. The Fundamental Directives point out the necessity to "create and introduce in manufacture basically new techniques and materials, and advanced technology," as well as to "use electrochemical, plasma, laser, radiation, and other highly effective methods of machining metals, materials and articles with the view of substantially improving their properties." Let us indicate two practical problems that fall into this category, and are solved by mechanics in conjunction with physics. This is, first of all, the application of powerful laser beams for cutting, welding, and heat treatment of metal surfaces, and in other technological processes. It is pertinent to point out that the production of powerful gaseous lasers itself requires precise gasdynamic investigations and, also, the determination of deformation of their mirrors. The laser must be a reliable durable instrument of small overall size, and convenient in operation. This poses some additional, by no means simple, problems to mechanical engineers and scientists.

We would also point out the interesting, from the practical point of view, investigations of the effect of a powerful electromagnetic pulse on copper, aluminum, steel, tungsten, niobium, and certain other metals, which sharply increase their plastic deformation limit and, sometimes also their strength. This is important, for instance, for increasing the effectiveness of metal forming by pressure and opens the way for creating new composites with a metal base.

14. Mechanics, thermodynamics and chemistry. Stability of chemical reactor operation at the optimal mode. One more problem of mechanics posed by industry, which has to be solved in conjunction with other scientific disciplines, is the investigation of thermal and diffusion processes with chemical reactions taking place in a moving homogeneous or disperse medium, a problem of so-called chemical hydrodynamics. Its application is in the domain of intensification of a number of technological processes in the chemical, petroleum processing, metallurgical and other branches of industry.

The basic calculation of chemical reactors with a closely-paced or suspended layer, of bubbling reactors, drying and other similar processes is based on the laws of multiphase mechanics, i.e. of the motion of liquid and gas in a porous catalyst medium in the presence of chemical reactions, and also on the laws of diffusion and thermal interaction between particles, drops and bubbles, and the reacting stream.

The development and research into new technological schemes must continue, using mathematical models capable of simulating more exactly real processes, taking into account the unsteadiness, heterogeneity and the complex kinematic dependence of the chemical reaction rate on concentration and temperature. Investigation of processes with turbulent motion is important in the study of heat and mass exchange with the medium.

Heat losses of a chemical reactor increase almost linearly with temperature, while heat emission is essentially nonlinear (Fig.5). Their equilibrium, as a rule, occurs at three different temperatures: some fairly low, some intermediate, and some high.

The equilibrium at steady low and high temperatures is stable, while at the intermediate temperature it is unstable. It is, however, the latter at which the reactor is most productive. To stabilize its operation in that state it is necessary to resort to cybernetics or, putting it more simply, to introduce additional control of teperature based, for instance, on its time derivative or on the deviation from the best specified value.

The development of chemical reactors working to a given program under conditions of forced unsteady mode is urgent.

Solution of similar problems, with additional factors affecting the operations of a chemical reactors, such as convective transport and longitudinal diffusion taken into account, represents now one of the main tasks of chemical hydrodynamics.

15. Mechanics and practice. New branches of mechanics. Investigation of concrete problems occurring in engineering was always one of the main features of mechanics. Reference to practice always enriches science with new ideas and new concepts.

Solution of practical problems, collaboration between scientists in the field of mechanics and engineers, and the assistance given to the latter in their practical work contributes to the development of mechanics as a fundamental science. In the final count it leads to the widening of the field of application of mechanics in engineering, and to a deeper theoretical and experimental investigation of its own problems.

Mechanics has always drawn the material for theoretical constructs and generalization from practice. A classical example of this from the past is the creation by N.E. Joukovskii and S.A. Chaplygin of the theoretical base of aviation and, also, of the theory of the hydraulic shock proposed by Joukovskii in connection with that eminent scientist's participation in the investigation of numerous breakdowns during the construction of Moscow's water supply system.

Now we witness the emergence of many new branches of mechanics related to practical problems of astronautics and rocketry, such as the motion of solid and elastic bodies with cavities partly filled with fluid, the control of rocket motion and the calculation of spacecraft trajectories and, also, gasdynamics of re-entry capsules and the calculation of heatproof coatings. These are new problems of hydrodynamics of stratified fluids, internal ocean waves, the construction of dams for hydroelectric power plants, explosive welding, new theories of solid body fracture consequent to crack formation, the theory of stability loss under sudden loading, the elastic contact of rubbing bodies in the presence of wear, the theory of simultaneous motion of mixtures, particularly in the presence of chemical reactions, the theory of deformation of plastics, fiberglass materials, and other composites. To these also belong new theoretical concepts in analytic mechanics, in the theory of motion complicated by shocks, the rotation of a body on a string, the theory of behavior of gyroscopes in gimbals controlled by electrostatic and magnetic fields, the theory of ball bearings, and many others, including the new problems of oscillations, control, and optimization.

16. Mathematical and physical experiments. Physical experiments. Instrumentation, equipment, and manufacturing facilities. The successful development of mechanics needs constant reference to experiments. At present, the so-called mathematical experiment has emerged besides the physical one. It is essentially the analysis of solution of sometimes most difficult but clearly defined problems with precisely formulated equations and initial and boundary conditions of motion. A kind of dialogue develops between the scientist and the computer.

The mathematical experiment is a powerful tool of scientific investigations. We would recall that the so-called detached shock wave in front of a fast moving body in the atmosphere such as a meteorite or a spaceship returning to the Earth, was investigated by that method.

The physical experiment is one of the principal, if not the principal tool of mechanics. It is necessary in a number of cases for investigating a phenomenon as a whole, to obtain a deeper understanding of internal processes in bodies, for establishing the relation between mechanical phenomena and the fine details of material structure, for the more precise determination of laws of deformation of bodies under complex and extreme conditions of motion such as high pressure and vacuum, at high or very low temperatures, subjected to the action of laser radiation, to the effect of various fields, as well as of chemical reactions with non-uniform density and temperature distribution in the fluid and statistical distribution of elastic properties of solids, etc.

Fine optical, spectro- and radiometric methods of measurement are now available in mechanics, including electromagnetic, ultransonic and nuclear, methods using laser and other techniques, in particular methods of measuring high-speed processes and of paramagnetic resonance.

Experimental research needs shock tubes, machines for combined loading of specimens of various materials, launching stands, powerful plasmotrons and lasers, test tanks and, finally, computers with very large memories. Facilities for quickly providing special equipment for experiments, for instance, for determining mechanical and physical properties of new plastics and their melts, the effect of electric current on the plasticity of metals, for carrying out technological operations by means of explosions, for piercing (more excactly for flushing out) holes in steel plates by water jets with polymer additives, development of flame operated lasers, and of holographic equipment for the investigation of residual stresses in welds, etc.

Many cases require the setting up of experiments under natural conditions. In this category are those involving fairly extensive motions of bodies in the atmosphere in order to determine the conditions governing the 'ablation' of the protective coating, sudden adhesive icing of icebreakers, and finding means for combating this trouble, the determination of actual errors of an inertial navigation system mounted on moving objects, seismological measurements, investigations of motions of the ocean and atmosphere, the study of technological processes such as crystallization under conditions of total weightlessness and many other.

The mounting and execution of experiments requires considerable means and effort, modern instrumentation and automated processing of experimental data, availability of well organized workshops and manufacturing facilities with appropriate equipment, materials and tooling.

Scientists warmly welcome the words of comrade L.I. Brezhnev at the 26-th Congress of the CPSU that "the needs of science must also be given close attention, scientific establishments must be provided with suitable equipment and instrumentation, and experimental production must be extended," as well as the statement in the Fundamental Directions: "to strengthen the material and technical basis of scientific research, project investigation, design organizations, and higher education establishments."

This has a direct relation to mechanics. Comrade L.I. Brezhnev, speaking on the role and *responsibility of the whole system of scientific research stated in the Summary Report:* "This system must be much more flexible and active, intolerant of sterile laboratories and institutions." This also must not be forgotten!

17. Variational problems of mechanics. Control and optimization of mechanical systems and technological processes. Economy of energy, labor and materials. In the Fundamental Directions the problem of economic and social development in USSR in the years 1981-1985 and in the period to 1990 is defined as follows: "To ensure the efficient utilization of natural, material, and labor resources as the decisive and most effective means of increasing the national wealth of the country..." The Report of comrade L.I. Brezhnev to the 26-th Congress of the CPSU states: "Intensification of the economy and of its effectiveness, translated into the language of practical business, means, first of all, that production must outstrip the expenditure incurred on it, so that higher output is achieved with more efficient use of resources." The realization of these aims requires the development of the most effective, rational, and economic technical solutions. Here, the scientists working in the field of mechanics can and must make a considerable contribution. Research in the domain of control and optimization of mechanical systems and technological processes plays a large part in this. Such problems are common to many branches of mechanics, and are akin to cybernetics and the theory of control. The essence of these problems consists of finding control actions of parameters (e.g. external forces, geometric shape of bodies, etc.) for which the motion of equilibrium of a mechanical system satisfies the beforehand imposed conditions and is, in one sense or another, optimal. The expenditure on material, working substance or energy, precision or speed or a production operation, or strength or stability of a designed structure can be used as the criterion of the quality of a process /or product/.

Optimal control investigations were originally developed in connection with the calculation of optimal trajectories of flying machines, aircraft, and rockets. Subsequently, thanks in the first place to studies of Soviet scientists, method of optimal control were generally and universally applied. The development of computers led to their wide application in engineering for selecting optimal parameters of machines, machine tools, transport and lifting equipment.

The theories of differential games and of motion control with incomplete information, and of the control of oscillating systems were recently considerably developed. Study of these urgent problems must be extended first of all to the development of effective approximate and computational methods of calculations.

In the domain of mechanics of liquids and gases, the problems of optimizing the shape of bodies moving in a stream of liquid or gas, those of the control of heat and mass transfer processes in chemical reactors, and of plasma stabilization are akin to problems of optimal control.

In mechanics of the solid deformable body, very urgent are problems of designing and producing optimal structures that have the required properties of rigidity, strength, and stability with the minimum of material content.

All these problems have one common feature in that they are all of the variational nature, and that their solution requires a combination of deep understanding of mechanics, expert application of optimal control methods and of the use of computers.

Undoubtedly a wide and reasoned use of concepts and methods of optimal control in mechanics will enable the development of new, more perfect variants of technological processes, improve quality of products, reduce material and energy waste, and increase the effectiveness of engineering solutions in industry, building, and transport.

Conclusions. Mechanics as theory and in universal understanding. Teaching. Mechanics and developments in machines, materials, and production processes. The importance of mechanics and of the exceptional part it plays in the formation of all that is new in national economy is, unfortunately, not sufficiently clearly appreciated by all specialist, heads of ministries and departments, of scientific research institutions and higher education establishments, as also that what represent the mechanics of our days itself.

As a rule, it is judged by the content of theoretical mechanics studied in all institutions of higher education. It is, of course, necessary to explain the importance of theoretical mechanics as one of fundamental disciplines in university curricula, a kind of bridge linking mathematics and physics to applied sciences and engineering. It is here that a student is taught for the first time to think as an engineer capable of formulating and solving practical problems, to obtain final, reasonably rounded-off numerical results, and expertly prepare computer programs. He must learn to analyze the solution, establish its limits of applicability and the requirements for the accuracy of input data.

It is no less important to point out that theoretical (rational or general) mechanics is only an introduction, although essential, to the collosal structure of modern mechanics in the widest sense of this fundamental science. The point is that courses in other branches of mechanics, such as strength of materials, hydraulics, the theories of oscillations and control, kinematics and dynamics of machines and mechanisms, are not everywhere available. Principles of hydrodynamics, elements of the theory of elasticity and plasticity, analytical mechanics, and the theory of stability appear only in syllabuses of universities and in a small number of institutes /of technology,/, mainly of the mechanical engineering type. This is also true of other special problems of mechanics, such as the theory of plates and shells, of creep and aging, of filtration, and the mechanics of chemistry, plasma, and combustion.

It is necessary to show on specific examples that expert design and analysis of new machines, machine tools, and instruments, purposeful creation of new materials, particularly composites, development of high-performance new technological processes for the production of higher quality products, requires, as a rule, a deep understanding of mechanics, knowledge of its laws, and the ability to apply them in practice.

This is why scientists in the field of mechanics must respond to the appeal of the 26-Congress of the CPSU - to take the path of intensive development of the national economy of the USSR - by direct participation in the creation of all new /aspects/ in engineering, and in solving large and small problems of mechanics related to production.

"Science must be a constant 'distruber of complacency' indicating areas of incipient stagnation and lagging in which the present state of knowledge enables us to move ahead faster and more successfully." These words uttered by comrade L.I. Brezhnev at the Congress fully apply to mechanics. They define the style to be maintained by scientists of the Soviet Union.

Soviet workers in the field of mechanics warmly welcome the resolutions of the 26-Congress of the CPSU, and will be guided by them in their scientific and practical activities for the good of our great Fatherland.

Translated by J.J.D.