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# ON PROSPECTIVE TRENDS AND PROBLEMS IN MECHANICS OF CONTINUOUS MEDIA

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In this communication I propose to outline certain general thoughts on a number of basic methodological questions and on the essence of some prospective new trends in mechanics. I shall also describe some selected specific formulations of basically solvable current problems. It is obvious that a complete and thorough survey of prospective trends and, even more so, of important and interesting problems of mechanics is virtually impossible. I shall, nevertheless, attempt to point out certain current problems of macroscopic mechanics that are important from the point of view of understanding nature and of applications in technology.

The first and most characteristic aspect of the present state (which it should be stressed, is now undisputable, although in the past it was controversial) is the ever deepening interaction and bond between mechanics familiar to us from school days and contemporary physics and other natural sciences (chemistry, biology, geology, geophysics, and others). The difference between subjects and methods of research in physics and mechanics is frequently considerably smaller than that between problems in these disciplines themselves. It can be confidently said that the fundamental principles of physics and mechanics make these today a single indivisible whole, and that any differences can only be of a terminological character whether related to the essence of the matter or to methods of theoretical and experimental research. For instance, the general thermodynamic and electromagnetic properties of material bodies and fields — in other words, rheology — evidently belong to both pure mechanics and pure physics.

The close union between mechanics and physics is very fruitful. Many traditional problems such as the propagation of perturbations, establishment of equations of state, of kinetic equations, etc. which in the past were studied only in physics and chemistry have now become problems for mechanicians. Investigations of typical interactions in matter and in fields are inseparable from motion phenomena, and their successful study is only possible on the basis of theoretical and experimental methods already developed or in the course of development by specialists in the domain of mechanics. Many achievements in chemical reaction kinetics are now the results of theoretical and experimental research in the domain of mechanics.

The second distinctive feature of contemporary mechanics is its close relationship with technology. Fundamental research in the domains of physics and mechanics is strongly stimulated by the innumerable problems that arise in technology, industry, and in

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applications to other sciences. The link with practical applications is at the source of emergence of new fundamental problems with the support of research in various kinds of technological means and of the new advanced measuring equipment, in particular, of the automated systems of measurement and the processing of these on computers, and of all kinds of technical experimental facilities. All this provides the basis without which scientific progress is now unthinkable.

Further achievements in science and technology are, undoubtedly, inseparable from the methodological point of view, as well as from that of resolving practical problems and widening the knowledge of nature. While in the early days of formation of contemporary mechanics its source was the observation and description of celestial bodies — celestial mechanics — now, besides problems of astrophysics and cosmogony which continue to exert a considerable influence on mechanics, the greatest importance has shifted to technological problems associated with the constructive description, usage, and the subordination of nature to man.

The most pressing problems facing many of our institutes and laboratories are related to the assimilation, introduction, and further refinement of latest achievements in measurement methods, setting-up of experiments and the processing of results of these, all of which are associated with problems of simulation.

The third prominent feature is the availability at present of powerful computational and experimental facilities which make it possible to effectively solve any requisite, correctly and well formulated, specific problem. Further successes in research directly depend on the development of new models and schematized formulations of problems, and are related to the solution of such specific problems or some current problems. The emphasis in creative research has now shifted to problems of simulation and the effective formulation of new problems.

Properties of bodies and fields, and of related processes with complex indivisible reactions of various nature, such as mechanical, thermal, electrodynamic, chemical, nuclear, and other interactions, are assuming an ever increasing importance. The study of such phenomena results in a substantial widening of the range of states of bodies and fields. For instance, it becomes necessary to define states of deformable bodies that are close to failure; states at very low or very high densities and temperatures of matter have acquired considerable importance; large energy transformations, physicochemical and other processes in inorganic matter and in living organisms, etc. are in that category.

To understand and describe such phenomena it is necessary to devise new models with internal degrees of freedom, introduce new characteristic macroscopic quantities, and establish for their determination new universal and special relationships or laws that are independent of the already known, such as the laws of conservation of mass, energy, momentum, etc.

A considerable number of publications appeared during the last decade, in which various new models were proposed. Some of these introduce various approaches to the formulation of relevant equations, or of particular or more or less universal properties of models of one kind or another. Others consider various formulas which in the opinion of their authors must become useful or find application for constructing new models. Such proposals are not infrequently only loosely related to the accumulated information, to the analysis of macroscopic consequences of the mechanism of microscopic interactions and of the structure of matter, as well as to the accumulated experimental data in physics. They are frequently of a formal mathematical character and in the main, explicitly aimed at achieving the greatest generality without consideration for the necessary reasonable simplicity and effectiveness of proposed models in subsequent application. It is always possible to obtain by mathematical tranformations simpler variants of models which would be subsequently accepted and fairly widely appreciated.

The new models are, as a rule, more complex than the known ones because of the nature of the problem, and this is further aggravated by the introduction of artificial and inexpedient complications.

This situation makes it difficult to understand a number of such works, with the result that they are seldom studied and often altogether ignored. In some cases it is simpler to develop and propose "one's own" model than try to understand and critically assimilate models proposed by other authors.

The theory of modeling deformable media is flooded here and abroad by the muddled amateurish tangle that baffles many specialists and often confuses students. As the result of using bad examples they lose their guidelines and the rational style in their work on the formulation of new problems.

It is evidently not possible to expect complete rationality and strict order in the formulation of new ideas. The development of rational foundations and the consideration of methodological bases for the theory is, however, expedient. It is advisible to take into consideration in these the theoretical devices that have proved successful in the practical and historical planes, the accumulated methods and the manifold foundations of physics.

An important aspect of the current stage is the necessity to modify our concepts of the relation between the theoretical modeling of investigated phenomena and experimental data. Certain discrepancies between experimental results and useful good models, that are nevertheless widely accepted and used in special cases in science and technology, have recently come sharply into prominence. I am, however, far from asserting that all proposed models, even those that are obviously wrong, are useful and have the right to exist. In this respect I am rather inclined toward the extreme opposite point of view.

While very wide ranges of remarkable agreement exist between reality and basic physical models, such as the Euclidean space, perfect or viscous fluid, or the elastic body (athough only in appropriate ranges that are inadequate for applications), the conformity of new models, such as of plastic bodies, plasmas, or many kinds of turbulent motions of liquids and gases with experiments is confined to a very narrow class of related phenomena and ranges. Generally speaking, there is a more conspicuous absence of clear agreement with experimental results.

For example, this is the case with the Tresca and Mises theories of plasticity which must and can be applied to states of high internal stress for certain load paths in bodies, even then when creep and many other properties of solid bodies begin to appear in experiments.

Although the use of classic models of the plasticity theory presents obvious advantages, it must be appreciated that their agreement and, generally, that of any plasticity theory models with experiments is somewhat tenuous. To those thinking along classical lines this problem may lead to the essentially unavoidable feeling of frustration and disillusion.

A similar situation is characteristic for many other new models, which does not, however, greatly diminish their practical value. It is useful to bear in mind that idealizations and schematizations are always present in definitions of theoretical models for media, fields, and processes, as well as in the formulation of specific design problems. Further-more, theoretical models are scientifically compared with the results of particular "neat" laboratory experiments, while in reality we have to deal with considerably cruder conditions. This increases the arbitrariness of approximate definitions of actual situations.

All this compels researchers and users to take a more thorough look at the essential features and the adequacy of requirements for the theoretical construction of models. It is obviously sufficient from the application point of view if the proposed models provide an explanation of the effects that take place, give reasonably complete answers to posed practical questions, and outline the sought solutions in an acceptable form.

It should not be forgotten that for a clear appraisal of the essence of a problem, the "discoveries" of "true" properties and laws related to media and actual processes are, in fact, nothing more than some invented approximations or rough initial concepts that are reliably admissible, and which may be invalidated by subsequent more detailed and refined investigations. At best they are to be taken as satisfactory or entirely unsatisfactory approximations.

Powerful methodological achievements, rigor and accuracy in the formulation of problems and in the derivation of their various solutions are prominent features of mathematics.

In mechanics, physics, and technology, as in mathematics, in the final stages of formulation of laws and many proposals and recommendations, it is necessary to substantiate the validity of proposed schematized models and of statements of problems under specific conditions which would make it possible to outline accurately and reliably the essential properties of objects and processes in nature and technology.

It is also clear that engineering projects and inventions suitable for mass production, as well as those related to individual objects, must be treated with utmost care.

In natural sciences and technology, as distinct from pure mathematics, research is associated with the use of experiments and is required to yield urgently and without fail substantiated answers to current problems of practical application and of knowledge of nature.

The need to reduce and bring some order in the flow of publications on various kinds of models of continuous media brings forth the question of compiling a monograph on the general theory of modeling mechanical objects on a unified basis. Such monograph must contain, besides the description of methods for constructing specific models, a complete and clear description of good fully worked-out examples of new models needed for prospective scientific developments.

Below we shall not dwell on detailed general theories and methods. Instead we present a considerably enlarged but incomplete list of unconventional models that were considered in scientific publications in the last three to four decades. These are:

- models of nonlinearly elastic bodies;
- models of non-Newtonian liquids and gases;
- models of plastic bodies with hardening;
- statistical and dynamic models of continuous dislocations;
- Cosserat and similar more general models with internal degrees of freedom;
- models of solid deformable bodies with allowance for transient effects;
- models of deformable media with allowance for thermodynamic effects of derivatives of unknown functions of various orders with respect to coordinates and time;
- models of heterogeneous and anisotropic deformable solid and liquid bodies, in

particular, of liquid crystals;

— models of material media which interact with radiation, in particular, of those subjected to neutron bombardment;
— models of suspensions of liquids and gases containing solid particles;
— models of liquids with bubbles;
— models of mixtures of various substances and of their phases with allowance for phase transition, chemical and nuclear reactions, diffusion, radiative heat transfer, and viscosity;
— models of various kinds of turbulent motions of liquids and gases;
— models of material media interacting with an electromagnetic field (plasma, interaction between body and light, magnetizable and polarizable liquid and gaseous media, liquids with magnetizable and polarizable particles in an electromagnetic field, and so on);
— models of various types of soil (such as rock, ice, snow, and others);
— models of ceramic materials, particularly at high temperatures;
— models of filtration of liquids and gases in soils and grounds;
— models of substances of high and ultrahigh density;
— models of gas and plasma at large electrical discharges;
— models of matter and fields in atmospheres and in the space surrounding planets and stars;
— models of various kinds of discontinuity structures, contact and boundary layers in liquids, gases, plasma, and solid bodies;
— models of plates, shells, rods, and various deformable membranes;
— models of numerous biological objects and processes;
— models of liquids in which macroscopic effects are of quantum character;
— models of space-time and of various physical fields.

These are examples of prevalent models under development and are already appearing in various applications,

Let us now outline prospective and actual trends and specific problems which are to be developed and resolved with the use of classical models or of those listed above, or of some special new models which will have to be developed in the nearest future.

1°. First priority must be given to the development of numerical methods suitable for solving problems on computers combined with further development of experimental research methods for solving existing problems.

Owing to the availability of computers our ideas about the solvability of mechanical problems are being revised. For instance, many problems of hydro- and aerodynamics related to unstable motions of liquids and gases in the presence of discontinuity surfaces, as well as problems of combined elastic-plastic deformation of bodies, whose solution by analytical methods was earlier impossible, are now successfully solved on computers by numerical methods.

Although numerical methods are well developed and have yielded numerous results in the domain of aerodynamics, and partly in that of hydrodynamics, solutions of problems pertaining to the state of elasto-plastically deformed bodies are few. Such calculations must be developed on a wider scale.

The refinement of meteorological theories and of numerical methods of weather forecasting are, evidently, of considerable importance.

Further development of stable and effective algorithms and programs for the numerical solution of mechanical problems is of considerable importance in the use of computers. The development within the framework of the more complex models of methods for solving problems in terms of general-purpose integral equations and algorithms of the type of finite elements is particularly necessary.

We particularly stress the already generally understood proposition that the creation of new experimental facilities, implementation of new methods of measurement, and the processing of these has always been, and will remain in future the basic driving force in the development of mechanics, as well as of many other sciences.

2°. During the last few years a considerable shift became apparent in the theory of strength and failure of deformable solid bodies. This was prompted by the evolution of the theory of cracks, which led to a better understanding of the many factors that cause failure which can be considered as a phenomenon of over-all instability. In many cases, but not always, it is induced by local conditions which determine the initiation, accumulation, and avalanche-like growth of cracks.

This shows the necessity for the deeper understanding of failure criteria. Fracture is at present the subject of new appraisals which takes into consideration the various failure mechanisms in different materials, the effects of production technology on components, of the design of these, of considerably increased or lowered temperature, of the presence of initial stresses, as well as the properties of initial and acquired anisotropy.

Local and general criteria and mechanisms of fracture of various products may differ depending on the materials (such as mono- or polycristalline, polymer, ceramic, composite, and other) used in their production. Failure is, as a rule, preceded by the appearance of dislocations, plastic strains, residual creep strains, and other time-dependent effects. Because of this the theory of brittle fracture and time-dependent failure is usually formulated in close relationship with the theories of elasto-plastic, visco-plastic, visco-elastic, and other models of deformable bodies.

The phenomena of strength and failure are at present considered in close relation with the state of stress pattern and with the introduction of special characteristic internal mechanical parameters of the scalar and tensor kind. The latter are determined on the basis of separate physical assumptions that conform to data obtained by processing the results of mass experiments. The analogy with the processes of melting and phase transformation may be used for a qualitative and quantitative description of failure.

The resistance to dynamic and cyclic loads, vibration, and fatigue with allowance for thermal and other physical effects, including that of exposure to various kinds of radiation, are obviously of considerable importance for many structures and materials of contemporary technology.

The logic of evolution of the theory of strength and failure compels scientists to treat these physical properties from the point of view of thermodynamics. This requires the determination of the introduced new internal parameters by stipulating certain "principles" or, simply, corresponding equations of thermodynamical nature that conform to experiments.

Accumulation of practical experiments, empirical formulas, and various conclusions derived by statistical processing of experimental data obtained in laboratories, manufacture, and service on various machine components in various branches of technology are of considerable importance and support in this domain.

Experience shows that the traditional methods of estimating the strength of various products and structures need theoretical clarification and further refinement.

The contemplated new concepts of the failure phenomenon and of its treatment undoubtedly provide favorable prospects for the development of theories of strength on essentially new foundations, which may have considerable practical value in critical situations.

3°. Mechanical problems in the chemical production technology must be quoted as the new and important development in mechanics. While not long ago the basic problems of mechanics were, in the main, concerned with celestial mechanics, aviation, motions of bodies in water, rocketry, explosions and collision of bodies, problems of structures, petroleum industry, processes in hydraulic and gas machines, etc., the mechanical problems of chemical technology are coming now to the fore.

Many processes of chemical production take place in laminar or, as a rule, in turbulent streams of gases or liquids, which often contain bubbles or solid particles, in the presence of chemical reactions of various kinds or phase transformations.

The quality of such processes is most intimately related to the mechanical properties of gas or liquid flows in these.

In many instances specifications for practically convenient processes are interpreted in terms of hydro-aerodynamic conditions imposed on fluid motions. The setting-up of bubbling motion modes in mixtures and of chemical reactions in a boiling layer represent hydro-aerodynamic problems. Heat transfer, the uniform distribution of various characteristic quantities, elimination of overheating or corrosion, etc. are problems associated with these.

Solution of such problems must be based on theoretical methods of modeling of continuous media by new models and, also, on various kinds of laboratory and other experiments set-up in conformity with the new concepts of models of continuous media.

Many important and as yet insufficiently understood problems, in particular that of the scale effect in the transfer of laboratory results to full scale objects, arise in this connection.

Problems of the determination of optimal channels in chemical plants and of optimal modes for technological processes under specific production conditions must be solved on the basis of mechanical investigations. Various production processes in space stations under conditions of weightlessness, in particular the growth of crystals merit investigation.

One of the basic problems is the elucidation of stability of suitable modes of liquid and gas motions in the presence of chemical reactions and of measures for ensuring their stability when required.

4°. An ever increasing importance is being attached in the last few years to the control of processes in continuous media and, in particular to the suppression of various threshold instabilities, whose characteristics are nonuniformly distributed over the volume in an unsteady manner, by means of the interaction of continuous systems.

Generally speaking, we have the problem of interaction between two continuous systems one of which performs the basic technological functions of the controlled processes with specified motions of the flow of required structure and properties, determined by practical requirements. The second is an auxilliary system which controls the characteristics and the dynamic phenomena of the first system. The second control system is selected by the designer to suit the specified objectives. Both systems are defined by partial differential equations. Basic interactions may be realized along corresponding interfaces at which boundary conditions must be satisfied. These interfaces and related conditions can be controlled as necessary by varying the rheological properties of the second system and by the external action on that system of mass forces, such as electromagnetic forces, and various other means.

It is also possible to use a system of suitably selected sensors which feed to the control equipment information about perturbations in the basic system and about the characteristics of states developing close to that specified for the running process and, also, control external opposing or damping influences, thus suppressing the development of undesirable effects.

In these problems the determination of phenomenological properties of the controlling medium and of optimal automatic actions for ensuring the attainment of specified aims is, besides the description of phenomena taking place, of fundamental importance.

New problems are, thus, created in which suitable rheologies of the continuous media for the control of the investigated unsteady processes are to be selected and obtained.

An interesting new and extremely important and constructive theoretical problem concerns the methods for ensuring phenomenological properties and the execution of programs that are automatically adjusted depending on the behavior of investigated phenomena with the view to improving their quality and stability.

It is theoretically possible to visualize a control by internally distributed sources of energy; however, this is impractical under real conditions. Such control system can have the form of external shells or composite media representing a system of thin shells.

Although work is carried out at present in this new and important domain of continuous media mechanics, it is nevertheless greatly desirable to extend the scope of research in that domain and widen the application of its results.

I would point out that the general ideas outlined above have been embodied in problems of ensuring the stability of motion of high-temperature plasma. The principles of control have recently made possible the attainment in experiments of record-breaking temperatures and extension of the existence of mobile plasma blobs.

The development of methods for maintaining molten metals in suspensions in vertical streams in the equipment for producing ultrapure metals is important.

Greatly promising is the application of these theories in the problem of maintenance of suitable modes of chemical reactions which, owing to their instability, are impossible without control systems.

Controls of this kind developed in the theory of continuous media can, also, be applied to elastic structures which without these are unstable, as for example, the rod loaded as in the known Euler's problem but subjected to external moments (at the lower fixed end) controlled by sensors located along the vertical cross section. It is possible to apply to a controlled rod loads in excess of critical and to maintain its vertical equilibrium position which is highly unstable without control equipment. Effects of the kind disclosed by this particular problem may have a considerable importance in numerous applications, for example, in the drilling of boreholes or deep drilling in metals.

Similar problems and solutions may be encountered in practice in connection with hydro- and aeroelasticity effects in ships, aircraft, and in various surface structures.

Control problems with varying rheology appear in biomechanics in models of the work of muscles, nerve excitation, and in some other phenomena in living organisms.

5°. Let us turn to problems of turbulent motions of liquids and gases, which had attracted the attention of scientists for a long time. Their efforts resulted in the introduction of characteristic parameters for numerous practically important phenomena, in the development of computation methods and the establishment of various and very useful qualitative and quantitative laws.

There are, on the other hand, some examples of indistinctness in the definition of characteristic effects, vagueness in formulation of the essence of emerging problems, and of the required, from the practical point of view, statements of problems and of contents of expected answers.

In investigations of turbulent motions of continuous media the typical characteristics of phenomena are introduced in the form of averages smoothly varying in time and over the volume as a substitute for or supplement to the irregular pulsing "true" small scale, but still macroscopic, states and motions of "moles".

The various methods of introducing averages evolved in the theory of turbulence can be used in other theories of mechanics of continuous media, but it should be appreciated that the basic idea of averaging is connected with the introduction of averages as virtually "constant" quantities in some small region of averaging.

It is useful to remember that the comparison of local averages determined with respect to time in experiments with turbulent streams, with calculated data cannot reflect the finer points of various theories owing to differences in the theoretical methods of averaging.

Basic concepts, such as kinetic and internal energies, internal stresses, coefficients of turbulent viscosity, etc. can be applied to averaged quantities. Such quantities and the related equations similar to the law of conservation, equations of state, etc. must take into account the method of averaging experimental data.

Considerable criticism may be expressed about some of the theoretical works on turbulence, in particular, some ineffective statistical theories.

As a mature problem I shall point out that some of the existing theories of turbulence and current methods of processing experimental results are in need of revision of their validity and of a radical critical shake-up. It is always necessary to examine the applicability range of turbulent motion models, either existing or under development, for various media.

The well proved classic and new means for measuring flows, particularly the probing of these by various beams and the application of holographic methods, are now successfully applied; possibilities exist for setting-up systematic precise physical experiments which until recently were carried out on an insufficiently wide scale. It is hoped that such experiments will lead to a better understanding of origins of instability in conditions of laminar flow, and of the turbulent separation of the laminar layer, and that it will become possible to determine the interaction of liquids and gases with various isolated or tightly distributed suspended particles, drops, or bubbles. It may become possible to observe and describe the main features of chemical and phase transformations in turbulent flows, to observe the interaction of flows with particles and walls, with the erosion or, conversely, with the building-up of boundaries, with free surfaces, and to describe the effects of flow twists, of nonuniform temperature distribution, etc.

For instance, it is known that polymer additives considerably affect the turbulent boundary layer at solid walls and in close vicinity of free flow boundaries. These effects are due to the damping of high-frequency oscillations by the addition of polymer particles or to the presence of various kinds of small particles of various substances.

It is necessary to extend the investigation of flow properties and of effects associated with internal turbulent stresses and the characteristics of mixing in flows in the presence of additives (for example, polymers of various solid particles, or long fibers). It is necessary to study the formation of sand alluvium, drifts of various kinds of sand, snow, etc. All these are important current fields of research that are rich in interesting results and prospective applications.

Although many practically useful results have been already obtained in this field, the present state of the art can only be considered as the beginning of a series of investigations that have yet to be carried out.

Closely associated with this category of problems are those of turbulent boundary layer control for the purpose of elimination of separation and lowering the friction drag of streamlined bodies by, for instance, setting-up forced oscillations of their walls, or by special purpose jet or other devices for injecting liquid or gas into the flow around the body or for sucking these from its surface.

The urgency of important problems concerning the laws governing separation flows and their properties, and also of the turbulent trail behind a streamlined body should be stressed.

The problem of internal aerodynamics of transport systems deserves considerable attention; it well may be that in future containerized transport systems in pipes will find wide application.

Experiments with small additives in turbulent flows and observation of highly twisted laminar motions of water solutions show the presence of rheological properties of liquids which are not represented in the Navier-Stokes equations.

Because of this it is not possible to consider as valid the opinion widely held in scientific circles and propounded in textbooks that the observed turbulent motions of water or air can always be considered as averages of "true" motions which conform to the Navier-Stokes equations.

It should be added to this that, from the practical point of view, it is evidently not always justified to expend a considerable amount of computer work for determining, on the basis of the Navier-Stokes equations, the true turbulent motions of a viscous fluid or the true motion of such fluid at loss of flow stability with subsequent onset of turbulence.

It is also obvious that the current basic problems of wave generation by wind on the surface of seas and oceans, and, generally, the problems of interaction between the sun, atmosphere, earth, and oceans, as well as those of weather forecasting are directly related to the effects of water and air viscosity. These problems must be based to a considerable extent on theories that take into account the properties of turbulent motions of liquids and gases.

Problems of convection and heat exchange in nature and in various kinds of technological installations generate numerous fundamental investigations of the mechanics of turbulent motions of liquids, gases, and plasma.

From the point of view of understanding nature, of considerable interest and promise are astrophysical problems of turbulent motions of matter in stars, convective intermixing inside stars, and the processes that take place in their atmosphere. Investigations of turbulent motions of cosmic clouds are important. In astrophysics and contemporary technology considerable importance is attached to the interaction of turbulent motions of plasma, and material media in general, with electromagnetic fields.

Although investigations in these fields are numerous and fairly intensive, a strengthening of the rational basis of theory and further concerted efforts of geophysicists, meteorologists, astrophysicists, and hydrodynamicists is required.

Many important mechanical and physical problems associated with nature conservation, in particular, the dispersal (diffusion) of various contaminants in turbulently moving media, belong to the class of problems whose investigation must be continued with increased intensity.

In connection with the environment conservation and many other technological problems it is necessary to continue the research into the interaction between hydro-aerodynamic and acoustic phenomena. This is a new field in which numerous unexpected effects, which in some cases induce additional turbulence in jets, while damping it in others are disclosed. In relation to jet propagation this may result in either a more intensive mixing coupled with a shortening of the jet range, or an attenuation of mixing and an increase of that range. These effects are basically related to the intensity and frequency of the emitted sound.

The propagation and attenuation of the aerodynamic noise originated in boundary layers by flow separation or generated by jets of aircraft engines remains on the agenda as one of the most important problems. Further practically important achievements in this field depend on the wider development of systematic theoretical and experimental research.

6°. The classical problems of hydro- and aerodynamics — the flow of liquid or gas around bodies — have been under vigorous development for almost hundred years. The beginning of this century which saw the birth of aviation is particularly noted for successes in this field. Each subsequent decade was distinguished by the commissioning of new wind tunnel type, hydrodynamic tanks, and from the thirties onward, by the creation of various large and small complex experimental gasdynamic facilities. Their development and the intensified theoretical research have provided the basic knowledge which made possible the fantastic contemporary progress in aviation, in marine technology, the astonishing development of rockets, all of which is generally reflected in the whole contemporary technology.

As the result of the scientific work during those years, a huge amount of experience was accumulated and a deep qualitative and quantitative understanding was achieved of numerous aspects of the interaction of liquids and gases with bodies moving at subsonic, super-, and hypersonic speeds. A great number of remarkable proposals related to lift and to very small or, conversely, very great resistance, and to other necessary information about hydro-aerodynamic effects on aircraft and various bodies moving in liquids were formulated and successfully realized.

Various barriers were overcome during that period. The geometry and other properties of moving forces and driving systems underwent numerous qualitative transformations. People have these astonishing results at their disposal and take them as something natural and due to them, without which our way of life and our means for further progress in technology and perceptual science would be unthinkable. It is now opportune to ask what should be our next steps on the paths of progress and which are the ways of overcoming new barriers that are coming into sight? First are the problems of further increase of the speed of motion of bodies in various media.

I shall not deal here with the contemporary scientific problems of aircraft aerodynamics. Considerable scientific achievements have been accumulated in this field, further progress is possible and is, to a great extent, predetermined by the already elucidated and planned objectives whose realization requires the concentrated effort of large collective bodies and a considerable expenditure of material resources.

The problem of producing mobile systems capable of comparatively prolonged movement under water or on its surface at sharply increased speeds of the order of say 100 m/sec is somewhat different. These are very low speeds in comparison with the speed of aircraft and rockets, but entirely unrealistic for ships, cutters, submarines, etc. moving in water. The basic limit is imposed here by the hydrodynamic resistance, in the first place by friction. It is necessary to evolve mobile systems in which the main part of hydrodynamic resistance must be reduced to between one third and one fifth of its present value, or even more.

Hydrodynamicists have been given the problem of working out recommendations for achieving the required sharp decrease of hydrodynamic resistances with the simultaneous submission of proposals for suitable propulsion systems to form a single whole with the moving object to ensure the attainment of considerably increased speeds of prolonged motion in water.

It is possible to obtain moderately high speeds by using conventional layouts with continuous flow of water past the body, good pressure recovery at the stern, and low friction at the body surface. Attempts of solving both problems can be made by improving the shape of the body and by controlling the boundary layer. Friction resistance can be lowered, in the first instance, by reducing the surface roughness of the body, and using various means, such as for example, the introduction into the boundary layer of polymer additives, water or other liquids.

Very "high" speeds can be attained by using detached flows which create cavities of suitable volumes separated from the water by free surfaces. This can virtually eliminate friction resistance. Such flow patterns are clearly observed when a body falls on the water at high speed.

The following fundamental problems arise in connection with the realization of similar horizontal motions of bodies in water:

1) the creation of a lift force for sustaining the body in a satisfactory horizontal motion;
2) the development of measures for ensuring the stability and controllability of motions of the body;
3) the determination of suitable methods for creating a cavity around the body by means of special disk-like adaptors or counterjets emitted from the body;
4) the development of rocket or hydro-reaction propulsion systems.

A systematic investigation of various alternatives of the cavitational flow of liquid around bodies using computers is indicated.

These are some of the fundamental hydrodynamic problems on the agenda in connection with the sharp increase of the speed of bodies moving in water.

Although it is possible to outline the paths for solving each of the enumerated problems, the preparation of recommendations acceptable for practical execution necessitates a considerable amount of theoretical and experimental research.

7°. The fundamental and most important development in contemporary mechanics of continuous media is the investigation and solution of problems of interaction between material media and electromagnetic fields.

The main problems of nature cognition in natural sciences, particularly in astrophysics, and those in the technology of thermonuclear energy applications are mechanical problems in which processes are essentially determined by the mechanical interaction between matter and electromagnetic field.

The effects of light and, particularly, of laser beams on various media and under various conditions are mechanical effects whose description and utilization are urgent mechanical problems for contemporary science and technology.

While until recently the main importance of the interaction between electromagnetic fields and bodies was attached to the extraction of Joule heat, more and more attention is given to the effects of interactions due to ponderomotive forces generated not only by conduction currents but, also, by the polarization and magnetization of matter, as well as by the obvious dependence of properties of material media on the magnetic field effects defined by the characteristic quantities appearing in Maxwell's equations.

Piezo-effects, magnetic hysteresis, magnetohydrodynamics, electrohydrodynamics, dynamic effects in discharge phenomena in gases and in MHD generators, processes in electromagnetic reaction propulsion systems and their modes of operation, and many, many other phenomena are now the subjects of new chapters of intense research in the mechanics of continuous media.

A successful investigation of the described phenomena necessitates, first of all, the rationalization of research methods beginning with the construction of new models of continuous media, which would be adequate for the complete description of mechanical phenomena associated with electrodynamics, the use of the considerable experience accumulated in physics, and with mechanics of continuous media.

Many publications describing new models of various phenomena have appeared recently. In these the problems of mechanics and electrodynamics are considered as a single whole.

Many variants of possible treatment of related problems have appeared in connection with this. Although the methods of modeling have been considerably advanced in this field, an understanding of the essence of such simulation in particular cases has not yet been reached even by highly qualified authors. The selection, description, and introduction of the most perfect models will greatly contribute to the effectiveness of these, which as yet cannot be considered perfect.

The numerous discussions that appear in print on the meaning of the term "energy momentum tensor" of an electromagnetic field in the presence of magnetization and polarization of matter can be quoted as an example of the above. The participants in this discussion overlook the fact that this tensor is to be introduced by convention, and that it always appears as a term in the sum with the energy momentum tensor of the matter and is to be defined in conformity with that convention. It is always only the sum of these that is present in equations of models, and that sum for a particular model is essentially unrelated to the accepted convention. It is worth noting that the essence of discussions about the separation of the energy momentum tensor is associated with the phenomena of magnetization and polarization of material media in whose models it is necessary to introduce thermodynamic and mechanical properties which depend on electrodynamic parameters. In the general case this leads to a change of traditional concepts of energy or momentum of a material body elements.

In these problems a not inconsiderable psychological difficulty is presented by the uncommon concept of the possible presence of nonzero macroscopic moments of momenta and of momenta of elements of a stationary material medium when that medium is magnetized and polarized.

The lack of clarity is sustained by the insufficient use in practice of various models of polarizable and magnetizable material media, models that would be suitable for the investigation of arbitrary motions in any electromagnetic field.

Because of the reasonableness of these or other conventions it is possible to produce various arguments, particularly those related to the unification of the concept of the magnetic field and to equations of moments of momenta, however all these arguments do not alter the basic meaning of the treatment of this subject, which is related to the possiblity of different conventions.

8°. It should be mentioned in conclusion that further successes in research in mechanics described above and in many other fields, which I have not mentioned, depend on the work of large bodies of highly qualified scientists. Their education and methodological skills in research must be formed by contacts with other scientists and by study of contemporary specialized scientific textbooks, monographs, and original scientific works which contain much of that has not been, as yet, included in the compulsory curricula and programs of universities.

Because of this the importance of scientific literature and the requirements for its high level have considerably increased. Consequently the writing of original monographs and general textbooks must be encouraged as the most important immediate aim. I would like to stress that, contrary to the widely held view, such books require from their authors much work and creative imagination of the same high quality and level as original scientific works, and that their usefulness and effect on scientific progress is not smaller than that of the most outstanding achievements.

We all know that participation in expert discussions, self-criticism, as well as constructive criticism strongly stimulate scientific progress, rid science of various prejudices, unmask inflated authorities, assist the promotion of talented and creative young scientists, increase the responsibility of scientists, and bring a positive contribution to the most important subject: the protection of true priorities. Further enhancement of the critical approach and the assurance of proper evaluation of works, the support of valuable achievements and of their introduction in practice are essential for building sound foundations of fruitful scientific research.

Authors of numerus oral and printed contributions propound various proposals and give valuable advice of an organizational and methodological character on the subject of increasing the effectiveness of scientific research, on the improvement of educational curricula, programs, and special courses at universities, as well as on the general improvement of teaching methods. However they forget in many instances to stress sufficiently the necessity to educate teachers and students, and to demand from them a high ethical standard. It should not be forgotten that the guidance of basically stable creatively active qualified leaders in universities and research institutes almost automatically ensures fruitfulness and high standard of work.

A profound understanding of scientific achievements is impossible without knowledge.

It is, however, possible to know a great deal and understand little. Knowledge without understanding leads to dogmatic methods of work with readily available formulas which, although useful, are insufficient for achieving real successes in the furtherance of science and technology.

In contemporary science, even in a particular narrow special region, it is impossible to know all of the available information, while on the other hand an over-all knowledge is required at the interface of its various branches. Hence it is important that university students obtain a good grasp of universal foundations of knowledge and of methods of problem formulation and solution, and one must strive at imparting to them the maximum deep understanding with minimum information, which is considerable and increases with time. The correct selection of that minimum in the light of prospective developments is a pressing current problem.

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# CONTACT PROBLEMS OF THE THEORY OF ELASTICITY IN THE PRESENCE OF WEAR

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The solutions of the contact problems of the theory of elasticity in the presence of wear is given for two cases. In Sect. 1 we consider the problems in which an initially curved beam comes in contact with a half-plane. One of the initial assumptions is that the distance between certain directrices along which the body in contact is sliding and the boundary of the half-plane remains constant. In Sect. 1 the contact between the curved beam and the half-plane is discussed at the assumption that the half-plane is subject to wear. As the result of the wear, the pressure between the beam and the half-plane is gradually reduced. It is naturally assumed that the pressure at the terminal points of the contact area will, in this case, be zero. The conditions characterizing the pressure at these terminal points can be established for various types of contact problems only under certain additional assumptions; this will be discussed below.

**1.** We assume that the initial form of a fairly thin beam is determined by the initial deflection $w_0(x)$. Let the initial form of the beam be that depicted in Fig. 1a. After the deformation caused by the contact with an rigid half-plane, the beam will assume the form shown in Fig. 1b. We assume that in the present case the beam is symmetric and is in contact with the elastic half-plane along the segment $-a < x < +a$. We shall further assume that the wear is abrasive. In this case the amount of material removed as the result of wear will be proportional to the work done by the frictional forces.

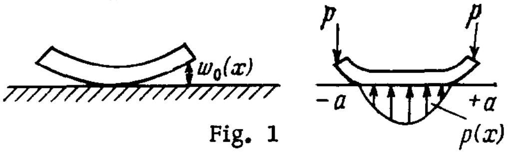

Fig. 1