1
Introduction

1.1
Goals and Methods of Continuum Mechanics

Continuum mechanics is that part of mechanics that deals with the movement of deformed gaseous, liquid and solid bodies. In theoretical mechanics, one studies the movement of a mass point, of a discrete system of a such points and of rigid bodies. On the other hand, in continuum mechanics, using the methods and results obtained in theoretical mechanics, one deals with the movement of such material bodies that fill the space continuously, and where the distance between points changes during the movement.

In addition to the usual media, that is, gas, fluid and solid, we also consider unusual media such as the electromagnetic field, the gravitational field and the radiation field.

In the following, we will discuss the most important problems that have given rise to the independent branches of continuum mechanics.

Since the forces that are exerted on a solid body by the gas or fluid that surrounds it depend on the movement of the gas or fluid, the study of the movement of solid bodies in a gas or a fluid is therefore closely linked with the investigation of the movement of a gas or a fluid. Hydromechanics as one of several branches of continuum mechanics deals with the movement of a fluid. Finally, the movement of a gas is discussed in gas dynamics. The problems of the movement of planes, helicopters, rockets, ships, submarines and so on gave the impetus for the massive boost in this research area.

The problems of movement of gas and fluid in tubes and different machines are of great relevance for the planning and calculation of natural gas pipelines, oil pipelines, pumps, compressors, turbines and other hydraulic machines. Applied problems in this field are the foundation for hydraulics.

The movement of gas and fluids through the ground and other porous media (filtration) is a very hot topic in the production of oil and natural gas. Thus, this field that deals with movement of gas and fluids through porous bodies is called subterranean hydromechanics.

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Large theoretical and applied importance has the problem of wave propagation in the media mentioned above, that is, gases, fluids and solid bodies. This field is referred to as wave mechanics.

Finally, another part of continuum mechanics deals with the movement of multicomponent and multiphase mixtures caused by different interactions between phases, exchange of heat and matter, phase transitions and chemical reactions. These problems are the foundation of physicochemical hydrodynamics.

The problems connected to the movement of conducting and charged media in magnetic and electric fields are dealt with by the field of magneto and electrohydrodynamics.

The methods of continuum mechanics can also be applied to the movement of bodies in a gas of low density, in outer space, and in stellar and planet atmospheres. The fields of continuum mechanics dealing with these problems are known as the mechanics of diluted gases and cosmic hydrodynamics.

Recently, a new field of biomechanics has come into the forefront which investigates the mechanics of biological objects, the flow of blood in living organisms, the contraction of muscles and which attempts to construct mechanicals models of the internal organs.

Among other important problems, the following needs to be mentioned: weather forecasting, theory of turbulence, movement of sand dunes in the desert, avalanches, burning and detonation as well as the theory of explosions.

Large parts of continuum mechanics are devoted to the investigation of the dynamics and the equilibrium of deformed solid bodies. The theory of elasticity provides the computational foundation for the planning of machines and buildings. Those parts of continuum mechanics that deal with the elastic properties of bodies having a complicated composition and with making provision for inelastic effects in solid bodies become more and more important. The theory of plasticity investigates the behavior of a solid body beyond the elastic limit. Of high importance is also the investigation of various types of material fatigue and taking the the memory effect for the dynamics and equilibrium of a solid body into account. With the invention of new compounds and polymers with composite internal structures, the need to develop new models for these compounds based on their internal structures has become evident.

It is impossible to enumerate all problems and applications of continuum mechanics. However, the above-mentioned examples are sufficient to make the conclusion that continuum mechanics is involved when dealing with a large set of theoretical and applied problems in science and engineering.

Continuum mechanics has also had a large influence on the development of a number of areas of in mathematics. For example, the theory of the wing of a plane influenced the theory of functions of a complex variable, the movement of a viscous fluid gave impetus to research about boundary conditions of partial differential equations and some problems of elasticity theory influenced the research of the theory of integral equations.

The solution of many important questions for applied problems has always necessitated the use of numerical algorithms. Therefore, continuum mechanics has boosted the development of numerical methods.

The following series of lectures about hydromechanics as part of continuum mechanics covers the research methods applicable to the dynamics of deformed bodies. We start by introducing a number of concepts, that is, the fields of velocity, pressure and temperature. We further show how mechanical problems can be reduced to mathematical ones whose solutions determine the properties and dynamics of the deformed bodies.

1.2 The Main Hypotheses of Continuum Mechanics

When investigating the dynamics of bodies, one has to exploit their real properties that depend on their internal structure. Every material body consists of different molecules and atoms which are in constant irregular movement. Certain interactions exist between the particles. For a gas, those are mostly determined by collisions. For a fluid, the particles are closer together than in a gas and thus the molecular forces, that is, London–Van der Waals attractive forces and repulsive electrostatic forces are important in this case. The strength and elasticity of solids are due to forces that are electrostatic in nature. If all forces are known, then it is, in principle, possible to create a theory of the dynamics of the material body. However, the complicated internal structure of the body and the huge number of molecules in the volume of interest are substantial hurdles for creating models of the medium. Therefore, it is practically impossible to consider the movement of one particle while taking into account the interactions with all others. Fortunately, however, when dealing with technical applications, there is no need to know the movement of all particles. One only needs to know mean values. In this connection, there are two methods to investigate the dynamics of the medium. The one is the statistical method that has been developed in physics and where the concept of a probability distribution is applied to the system under investigation, and one considers mean values of system data taken over all possible realizations of the system. The second method consists of arriving at a phenomenological macroscopic theory based on experimental observations and laws. In continuum mechanics, the second method is mostly used. However, in some areas, that is, when investigating the dynamics of heterogeneous multiphase media (emulsion, suspensions etc.), both methods are combined.

The methods of continuum mechanics are founded on two hypotheses. The first hypothesis is the continuum hypothesis which assumes that since the number of particles in any volume of practical interest of each material body is extremely large, the body can be considered as a medium that fills the volume in a continuous manner. Such a medium is referred to as a continuous medium. This idealization of the real medium makes it possible to employ the mathematical devices of continuous functions, and differential and integral equations for modeling the processes of interest in the medium.

The second hypothesis is the space-time hypothesis. In continuum mechanics, one normally considers the Euclidean space concept to be applicable so that a homogeneous global system of coordinates can be introduced. The version of mechanics that has been developed on the basis of this hypothesis is called Newtonian mechanics. In general, however, the time does depend on the coordinate system if relativistic effects are taken into account. By neglecting relativity, the time passes in the same manner for all observers. Such a time is referred to as absolute time. Normally, continuum mechanics investigates the dynamics of the continuum in Euclidean space, that is, continuum mechanics is based on Newtonian mechanics. However, in some cases, it is necessary to use the methods on non-Euclidean geometry and the theory of relativity, for example, when investigating the movement and deformation of boundary between different phases of a medium and also when considering the movements of objects in outer space at very high velocity.