Elasticity or plasticity?

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Elastizität oder Plastizität?

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A very interesting discussion is going on on elasticity and plasticity. I should like to contribute to it some further remarks.

A reversible (or elastic) deformation, as you all know, is the response of a material in the first stage of the loading process. It may be linear or non-linear. It is not accompanied by energy dissipation. (We confine ourselves to discussing isothermal processes).

Viscous flow is observed when the body is maintained for a long period under the action of external forces. This may be either reversible or irreversible; however, it is always connected with energy dissipation.

A plastic deformation is a kind of defence (self-defence) of the material against overloading. It is always irreversible and is always connected with energy dissipation.

Thus it may be seen that there is not only a quantitative, but, essentially, also a qualitative difference between elastic, plastic, and time-dependent phenomena.

The above remarks hold, as a rule, for any material; they are also true for our engineering materials from which our structures are made.

In consequence, the response of our engineering structures to various kinds of external agents depends (1) on the duration of the application of loads and (2) on their intensity.

The Theory of Elasticity deals with reversible phenomena, and is not interested in and, therefore, cannot account for such effects as the time-dependent deformation processes which are generally called the rheological (or viscous) phenomena as, e.g., creep, relaxation etc.; but it also cannot account for plastic effects.

On the other hand, the designer - a conscientious designer - wants to know what really is going to happen to his structure in the course of its existence, let us say, in a year, or two, or five; and perhaps also, what is going to happen if the structure - by accident or purposely - is overloaded, overloaded in comparison with the originally planned design load.

Thus, there is no contradiction and, of course, no competition between the "elastic" and "inelastic" approaches. Consequently, there is also no competition or clash between the Theory of Elasticity and the Theory of Plasticity: these theories simply cover different questions. Thus, they are complementary.

The Theory of Plasticity is, if I may put it in a somewhat simplified way, a kind of extension of the Theory of Elasticity.

It is to-day quite obvious that the Theory of Elasticity is a well developed and logically built up discipline. It has been worked on for about three centuries since Robert Hooke's famous statement "Ut tensio, sic vis" has been published*). Thus, he formulated one of the basic assumptions of the (physically) linear Theory of Elasticity (law of proportionality between strains and stresses) . The other assumption is that the deformations and strains are small (geometrical linearity) . With these two fundamental assumptions the elegant and impressive structure of the classical Theory of Elasticity with all the required basic principles, variational theorems, methods of solutions, comprising countless effective applications, has been established.

The Theory of Plasticity is not less important, however quite different, somewhat more complex and, moreover, far younger. The foundations of the mathematical theory of perfectly plastic materials were laid in two splendid papers by Barré de Saint-Venant and Maurice Lévy (C.R. Acad. Sci., Paris 1870) . But then, for about 30 or 40 years, nothing happened in this domain. Only in 1904 M.T. Huber, and later independently R.v.Mises (1913) and H. Hencky (1924) established the "energetic" yield criterion for the onset of plastic deformations in three-diemnsional states of stress. So the age of the Theory of Plasticity is to-day not even a hundred years, from which only the last 50 or even 40 years are of importance. It is quite clear that, under such circumstances, some questions are still open, especially for assessing the theoretical treatment of phenomena of work-hardening, finite deformations and some others. Anyhow, constant progress is being made in all basic and applied aspects and it is fair to state that the results achieved so far have already widened our basic knowledge and have well served numerous engineering branches.

In conclusion I should like to remark that man has always been and is very inquisitive creature: we examine everything, starting with ourselves, down to bacteria and virus, we reach out - at the other extreme - to the moons and galaxies. So I think it is quite natural that we cannot prevent people from being curious and having a penetrating mind in connection with the properties, life and reliability of our materials and structures in all the circumstances they have to face and also after they have exceeded the elastic range of response.

I also think that - so far - scientific research seems to constitute the only way of satisfying one's own personal curiosity being at the same time instrumental towards solving numerous social and public problems and needs; it likewise seems it will continue to be so in the field of structural engineering.

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*) R.Hooke, De potentia restitutiva, London 1678. As a matter of fact Hooke's principle of his balance spring was first expressed in a Latin anagram "ceiiinosssttuu" (1676), a form which commonly was used in scientific circles of the time to establish priority of discivery without actually disclosing anything that might be of use for possibly jealous collegues.