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PART IV.—STIFFNESS AND STRENGTH OF MATERIALS.

147. *Introductory Remarks.*—The straining actions which tend to cause a body or a structure to separate into parts A and B in the manner explained in Part I. are counteracted by the mutual action between the parts at each point of the real or ideal surface which divides them. In other words (see Art. 1), a STRESS exists at each point of the surface, the elements of which are A's action on B and B's action on A. If we consider the total amount of the stress, these elements each form one element of the straining actions on A and B respectively; but for our present purpose it is needful to consider, not the total amount, but the intensity of the stress. This in general varies from point to point, and at each point is measured by the stress per unit of area on any small area enclosing the point.

Either element (say A) may be regarded either as A's action *on* B, or as the resistance which A offers to the action *of* B, in other words stress may be regarded in two aspects, either as the cause tending to produce separation into parts, or as the resistance to such separation. It is under the first aspect that we shall chiefly regard stress, generally employing the word resistance when we wish to express the second idea. Stress then may be described as the straining action on the ultimate particles of a body. Conversely a straining action as defined in Ch. II. may also be described as the "resultant stress" on the section we are considering.

If the stress exceeds a certain limit, separation into parts occurs, and this limiting intensity of stress varies for different materials and measures the Strength of the material.

Accompanying the tendency to separation into parts we invariably find changes of dimension in the body and each of its parts, for no body in nature is absolutely rigid. Such changes are called STRAINS, and are of two kinds, changes of volume and changes of figure, or, in other words, changes of size and changes of shape. Changes of size in any dimension are measured by the ratio of the change to the original dimension considered; changes of shape consist in the alteration of relative angular position or distortion of the parts considered, and are measured by the absolute magnitude of the alterations in question. In most cases which concern us, both kinds of change take place together and are of exceeding smallness.

The strains produced in solid bodies by the action of forces depend on the nature of the material and on the kind of stress.

Bodies are either solid or fluid. A fluid may be defined as material which offers no resistance to change of shape, but only to change of volume, especially diminution of volume, so that any distorting stress, however small, will cause indefinite change of shape if sufficient time be allowed. On the other hand a solid body will resist a distorting stress for an indefinite time, provided that stress be not too great. In a fluid body at rest only one kind of stress can exist, namely, a pressure equal in all directions; hence often called "fluid" stress.

There are two extreme conditions in which a solid body may exist, the Elastic state and the Plastic state. Elasticity is the power a body possesses of returning to its original shape and dimensions after the forces which have been applied to it are removed. All bodies possess this property to a greater or less extent, and most (perhaps all) possess it to a great degree of perfection if the strains to which it has been exposed are not too great. Even so unlikely a material as soft clay is elastic if the force applied to it is very small. This may be shown by suspending a long filament, formed by forcing clay through a small orifice, by one end and twisting the other, to which an index is attached: on release the index returns to its original position.* In perfectly elastic material the recovery of size and shape on removal of the forces is complete, unless the tempera-

* See Robison's *Mechanical Philosophy*, vol. I., page 375. The original observation is said to have been made by Coulomb. Though frequently quoted it does not appear to have been verified.

ture has meanwhile varied: and the materials of construction may be regarded as approximately satisfying this condition, provided a certain limit stress be not overpassed. This is called the Elastic Strength of the material. It is also described as the "limit of elasticity."

When, on the other hand, the forces applied to the body are comparatively great, the material in many cases approaches the other extreme condition, the plastic state. In this state any forces causing a distorting stress beyond a certain limit, and so applied that disruption does not occur, will produce indefinite distortion, so that the material behaves like a fluid. Thus soft clay, lead, copper, or even malleable iron may be moulded into different shapes or drawn out into wire. In intermediate cases a body may exhibit the properties of the elastic and the plastic states combined.

We commence by studying matter in the perfectly elastic state. There are two different kinds of elasticity, — Elasticity of Volume and Elasticity of Figure. A fluid possesses the first kind only, since by definition it has no power of resisting change of shape: the second is characteristic of solids. In general a change of dimensions involves both a change of size and a change of shape, so that both kinds of elasticity are called into play together. In perfectly elastic material the strain produced by a given stress is always proportional to the stress, being found by multiplying the stress by a co-efficient or "modulus" of elasticity, depending on the kind of stress and the nature of the material. This property having been discovered by Robert Hooke is known as Hooke's Law. Further, if the stress be relaxed in the slightest degree the strain diminishes, that is, in perfectly elastic material, the elastic forces are completely "reversible" (p. 205).

The magnitude of the stress produced by the action of given forces upon a body depends very much on whether they are applied all at once or are supposed to be at first very small and gradually to increase to their actual amounts. The next four chapters will be limited to the action of a gradually applied load on perfectly elastic material. The experimental part of the subject is placed in the last chapter (Ch. XVIII.), but should be referred to constantly as required.