

more such uncertainty is removed, the more nearly perfect is the machine, and the more nearly does it comply with the conditions for which it was designed, and the more perfectly will it do its work.

DIVISIONS OF THE SUBJECT

We may divide our study of the machine into four parts (1) A study of the motions occurring in the machine without regard to the acting forces, this may be called the *kinematics of machinery*. (2) A study of the external forces acting on different parts of a machine, treating it as a structure which is not moving, or is moving uniformly and balancing forces by the ordinary methods of statics, the problems are those of *static equilibrium*. (3) A study of the forces due to the weights and shapes of the parts as well as to the external forces. (4) A study of the proper sizes and shapes to be given to the parts to provide for them sufficient strength to carry out the motions which the designer intended, and to be able to resist the applied forces. This is called *machine design* and is of sufficient importance and magnitude to demand an entirely separate treatment so that it will not be dealt with here.

We may begin on the first division of the subject, and shall discuss the methods adopted for obtaining definite forms of motion in machines. If we study the steam engine, which we have already discussed at some length, we notice that in any moving part the path of any point always lies in one plane. e.g., the path of a point on the crank pin lies on a plane normal to the crank shaft, as does also the path of any point on the connecting rod, and also the path of any point on the crosshead. Since this is the case the parts of a steam-engine mentioned are said to have *plane motion*, by this statement we simply mean that the path of any point on any part described always lies in one and the same plane. In a completed steam engine with slide valve, all parts have plane motion but the governor balls, in a lathe all parts have plane motion usually, the same is true of an electric motor, in fact, the vast majority of the motions with which we have to deal in machines are plane motions.

There are, however, cases where different motions occur, for example, we find that there are parts of machines where a point always remains at a fixed distance from another fixed point, or where the motion is such that any point will always lie on the surface of a sphere of which the fixed point is the centre, as in the universal