MACHINE DESIGN. PART I. KINEMATICS OF MACHINERY

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MACHINE DESIGN.

PART I.

KINEMATICS OF MACHINERY.

BY

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PREFACE.

In these notes an attempt is made, first, to give, as clearly and concisely as possible, the principles of mechanical motion in such a manner that their application can readily be made to any mechanism for determining the motion of any of its parts; then to show the methods of dealing with such problems as the designer meets daily. Long and tedious discussions have been avoided as far as possible, it is hoped, fully.

Subjects such as toothed gearing and couplings are taken up only to the extent of the forms that are in the most common use. But with these subjects, as well as all others, references to what are believed to be the best works in their lines are given frequently.

All available works on the subject have been freely consulted, but in no case has any matter which has not become common property by its frequent publication been used without the consent of its author.

The exceedingly clear and concise work of Prof. Albert W. Smith, of Stanford University, entitled "Machine Design," has been of most valuable assistance throughout. This work includes both kinematics and mechanics. To Prof. Smith, especially, the writer would acknowledge his obligations and express his thanks.

FORREST R. JONES.

MADISON, WIS., November, 1897.

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KINEMATICS OF MACHINERY.

CHAPTER I.

GENERAL PRINCIPLES AND DEFINITIONS.

MOTION OF A BODY.

1. When a body moves, there must always be another body with regard to which the motion occurs. Sometimes the statement that the movement takes place is all that is necessary to define it, the conditions being such that the reference body is clearly implied; but at other times a more specific statement is required. A simple example will illustrate: When a boat is running through the water at the rate of 12 miles an hour against a current of 3 miles an hour, the motion is clearly 12 miles an hour relatively to the water; but when referred to the land it is $12 - 3 = 9$ miles an hour.

The wheel of a locomotive furnishes another example: As the locomotive passes along the track, the wheel simply rotates with regard to the frame of the engine; but when referred to the track, the motion is a combined one of rotation and translation.

An examination of the motion of the piston shows a somewhat similar case: Relatively to the locomotive, the motion is reciprocating, its path being back and forth from end to end of the cylinder; but the motion is always forward with regard to the track when the locomotive moves forward, and *vice versa*.

A body entirely free to move may have motion in any direction according to the influences brought to bear upon it. In order for the motion to be a useful one, it must be constrained to such an extent that it will fulfil its required functions.

2. The three principal forms of constrained motion are as follows:

1st. **Plane motion.**—If a body having a plane surface on one side is placed against the plane surface of another body and moved so that the surfaces always remain in contact, the first has a plane motion relatively to the second, whatever the nature of the motion otherwise.

Thus, if a book is placed with one side on a table and slipped about without lifting its side from the table, it has a plane motion, due allowance being made for irregularities of the surfaces.

If a body does not have a plane side, it is possible to give it a plane motion by attaching three points to it so that they will rest and move on the reference plane, or by attaching it rigidly to a rotating shaft, or by the use of other suitable devices.

In general, *a body has plane motion when it moves so that a plane can be passed through it cutting a section which will coincide with the cutting plane throughout the motion.*

Rectilinear motion occurs when every point in a body moves in a straight line.

Rotary motion takes place when every point in a body moves in a circle.

2d. **Helical motion.**—When an ordinary screw is turned about its axis so as to pass through a nut with which it engages, it has a helical motion relatively to the nut. Every point in the screw, except those in its axis, has a combined motion of rotation and translation, the ratio of the magnitudes of these two elementary motions being constant for any point in or attached to the screw.

3d. **Spherical motion.**—If a rigid body is attached to another by a "ball-and-socket" joint which will allow it to move in any direction about the centre of the ball and socket, then every point in the body has a spherical motion when the body is moved in more than one direction about the joint. (Movement about the centre in one direction only would give the body a rotary motion.)

Spherical motion may be defined as the motion of a body moving so that every point in it remains at a constant distance from a centre of motion, but does not remain in a plane.

3. Relative motion.—Two bodies are said to have the same motion when they can be rigidly connected together during the motion without changing it in any way. From this it is evident that—

1st. **If any two bodies have the same motion relatively to any other, they have no relative motion, and vice versa.**

2d. **The relative motion of two bodies is not affected by any motion common to both.**

Any motion of a body can be resolved into two simple ones—one of translation and one of rotation; therefore, if two bodies

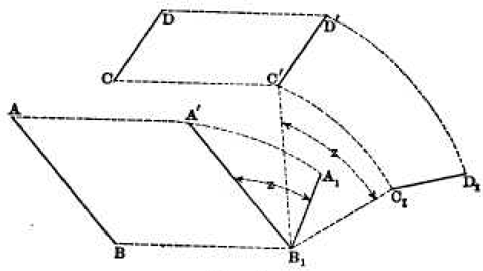

FIG. 1.

have the same motion, both can have their motions resolved into equal translations and equal angular rotations about the same axis.

Illustration.—In Fig. 1, let AB and CD be the initial positions of two bodies having the same motion, the final positions being A_1B_1 and C_1D_1. The change of position of AB can be accomplished by two motions, the one a translation from AB to $A'B_1$, and the other a rotation about an axis through B_1, passing through an angle z into the position A_1B_1.

The motion of CD can be resolved into an equal and similar translation from CD to $C'D'$, and an equal rotation z, about the same axis through B_1, into the position C_1D_1.

(It should be remembered that the bodies may be considered as being rigidly fastened together.)

When, starting from given positions, the (different) motions of two bodies are known with regard to the same standard, the motion of one relatively to the other may be found by giving both the same motion of such a nature that one will return to its original