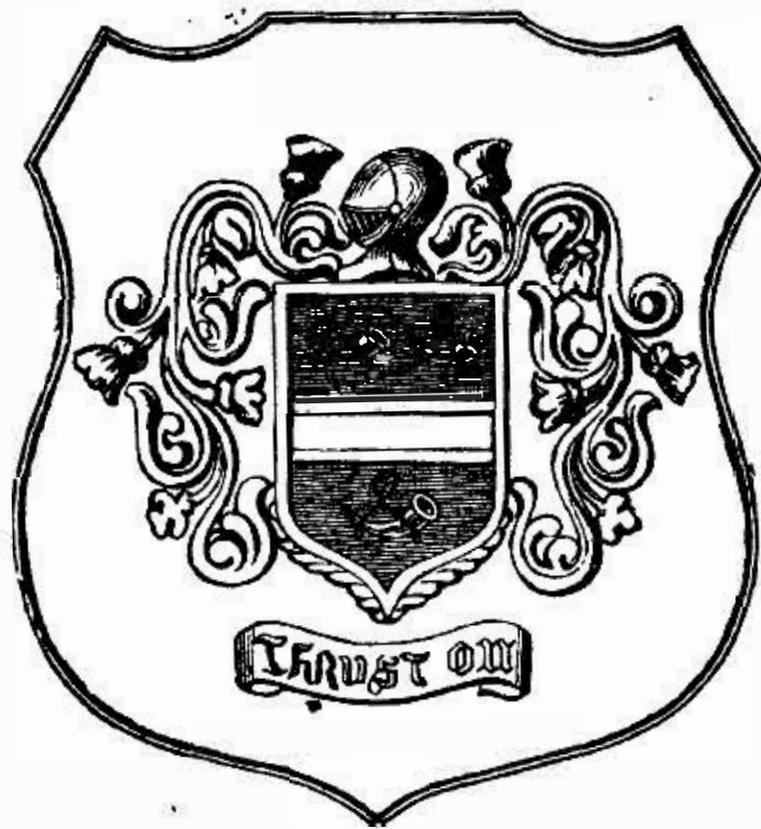


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# A MANUAL

OF

# MACHINERY AND MILLWORK.

BY

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## PREFACE.

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THIS book is divided into three parts: the first treats of the Geometry of Machinery; the second of the Dynamics of Machinery; and the third of the Materials, Strength, and Construction of Machinery.

Under the head of the Geometry of Machinery, machines are considered with reference to the comparative motions only of their moving parts; and rules are given for designing and arranging those parts so as to produce any given comparative motion.

Considering that the object of such rules is to adjust the dimensions of the parts of machines by processes of practical geometry, I have thought it advisable to solve every question by drawing, rather than by calculation, except in a few special cases where calculation is indispensable.

Many of the graphic rules thus obtained are made more easy and accurate, and some, indeed, are made possible which were not so before, by the aid of new methods of measuring and laying off the lengths of curved lines.

Two chapters of the first part are devoted to the detailed consideration of the movements of single pieces in machines. The remainder of the part relates to Pure Mechanism, as defined and reduced to a system by Professor WILLIS. The order in which the various combinations in mechanism are treated of is different from that adopted by him; but the principles are the same.

Several problems in mechanism are solved by methods which, so far as I know, have not hitherto been published; and which possess advantages in point of ease or of accuracy. I may specify, in particular, the drawing of rolling curves, and of some kinds of cams; the construction of the figures of teeth of skew-bevel wheels, and of threads of gearing screws, by the help of the normal section; and some improvements in the details of processes for designing intermittent gear, link-motions, and parallel motions.

Under the head of the Dynamics of Machinery are considered

the forces exerted and the work done in machines; the means of measuring those quantities by indicators and dynamometers, of determining and balancing the reactions of moving masses in machines, and of regulating work and speed; and the efficiency, or proportion in which the useful work is less than the total work, in the different sorts of moving pieces, and in their various combinations.

Considering that a convenient single word is wanted to denote the proportion in which the total work in a machine is greater than the useful work, I have ventured to propose the word COUNTER-EFFICIENCY for that purpose.

Under the head of the Materials, Strength, and Construction of Machinery are considered, *first*, the properties of various materials, as affecting their treatment and use in the construction of machines; *secondly*, the general principles of the strength of materials; *thirdly*, the special application of those principles to questions relating to the strength and the construction of various parts of machines; and *fourthly*, the principles of the action of cutting tools.

Great care has been taken to ascertain the values of the factor of safety and of the working stress in successful examples of actual machinery; and some of the problems respecting the strength of special parts of machines have not been published previously except in scientific journals and in lectures.

Authorities for facts and information are cited where it is necessary to do so. The following works are so frequently referred to, that it may be desirable to mention them here specially:—

WILLIS *On Mechanism.*

FAIRBAIRN *On Millwork.*

HOLTZAPFFEL *On Mechanical Manipulation.*

BUCHANAN *On Millwork*; edited by TREDGOLD and G. RENNIE with an *Essay on Tools*, by NASMYTH.

W. J. M. R.

GLASGOW UNIVERSITY, *June, 1869.*

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ADDENDUM TO ARTICLE 262, PAGE 297.

**Disengagements acting by Rolling Contact.**—In fig. 213, the radii A D and B E of the two smooth wheels to be connected are equal; but those radii may, if required, be made unequal: the essential condition of the proper working of the combination being that the angle, A C B, made at the centre of the intermediate wheel by the two lines of centres, should be a little less than twice the complement of the angle of repose. (See page 298.)

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ERRATUM.

Page 15, line 11; for "37" read "36 A."

# MANUAL OF MACHINERY AND MILLWORK.

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## ERRATA.

Page vi, line 27, after "*WILLIS on Mechanism*," insert "first edition, 1841; second edition, 1870."

Page 417, line 4 from bottom, for "D · D R," read "2 D · D R;" and for "2 D c," read "4 D c."

Page 417, last line, for "2 D c," read "4 D c."

Page 418, line 2, for "2 D c," read "4 D c;" and for "2 D," read "4 D."

Page 524, line 2 from bottom, for "3,200," read "6,400."

Page 551, line 7 from bottom, for "24,700," read "2,470;" and for "157," read "49.7."

Page 551, line 6 from bottom, for "7,524," read "752;" and for "87," read "27.4."

# A MANUAL OF MACHINERY AND MILLWORK.

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## INTRODUCTION

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**ART. 1. Nature and Use of Machinery in General.**—The use of machinery is to transmit and modify motion and force. The parts of which it consists may be distinguished into two principal divisions,—the *Mechanism*, or moving parts; and the *Frame*, being the structure which supports the pieces of the mechanism, and to a certain extent determines the nature of their motions. In the action of a machine the following three things take place:—*First*, Some natural source of energy communicates motion and force to a part of the mechanism called the *Prime Mover*; *Secondly*, The motion and force are transmitted from the prime mover through the train of mechanism to the *working piece*; and during that transmission the motion and force are modified in amount and in direction, so as to be rendered suitable for the purpose to which they are to be applied; and, *Thirdly*, The working piece, by means of its motion, or of its motion and force combined, accomplishes some useful purpose.

**2. Distinction between the Geometry and the Dynamics of Machinery.**—The modification of motion in machinery depends on the figures and arrangement of the moving pieces, and the way in which they are connected with the frame and with each other; and almost all questions respecting it can be solved by the application of geometrical principles alone. The modification of force depends on the modification of motion; and those two phenomena always take place together; but in solving questions relating to the modification of force, the principles of dynamics have to be applied in addition to those of geometry. Hence, in treating of the art of designing machinery, arises a division into two departments,—the “*Geometry of Machinery*,” or “*Science of Pure Mechanism*” (to use a term introduced by Professor Willis), which shows how the figure, arrangement, and mode of connection of the pieces of a machine are to be adapted to the modification of motion which they are to

produce; and the "*Dynamics of Machinery*," which shows what modifications of force accompany given modifications of motion, and what modifications of motion are required in order to produce given modifications of force.

3. **Strength of Machinery.**—In order that a machine may be fit for use, every part, both of the machinery and of the framework, must be capable of bearing the utmost straining action which can be exerted upon it during the working of the machine, without any risk of being broken or overstrained; and the dimensions required for that purpose are to be determined by the proper application of the principles of the strength of materials.

4. The **Art of the Construction of Machinery** consists of three departments,—the selecting and obtaining of suitable materials for the parts of the mechanism and framework; the shaping of those parts to the proper figures and dimensions by means of suitable tools; and the fitting-up of the machine, by putting its parts together.

5. **Division of the Subject.**—For the reasons explained in the preceding Articles, the subjects of this work are treated of under four principal heads,—Geometry of Machinery, or Pure Mechanism; Dynamics of Machinery; Strength of Machinery; and Construction of Machinery.