CHAPTER I.

ON THE WHEELS AND STUD-SOCKETS.

(2.) THE system about to be described consists of certain definite parts, including the principal forms which occur in the moving portions of trains of mechanism, the shapes and dimensions of which parts are so arranged as to allow them to be fitted together in a great number of different ways, and thus to compose various machines, with the assistance of a general system of frame-work, which similarly admits of being built up and composed of a few parts so contrived as to permit them to be united in various combinations. Especial pieces are added when required, as will presently appear.

Now every train of mechanism is composed of a series of moveable pieces,[1] each of which is so connected with the frame-work, that when in motion every point of it is constrained to move in a certain path. In by far the greater part of these pieces the path is a circle, or, in other words, the pieces revolve; and under this head also are included nearly all the pieces that are susceptible of being applied in common to a variety of combinations; that is, toothed-wheels, pulleys, or riggers, shafts, lever arms for link-work, and so on. Sliding pieces (in which the path is rectilinear) are usually formed with an especial object (excepting racks), and occur in such a manner that I have never found it advantageous to give them a place in the general system: this will be admitted when the nature of that system has been explained. Still less is it required to provide for pieces that move in curvilinear paths other than circular.

(3.) Toothed-wheels may be obtained of cast iron, and those which are fit for our purpose are of the kind employed in the construction of the smaller parts of manufacturing mechanism. Spur-wheels may be had in sets of selected numbers of

[1] See 'Principles of Mechanism,' p. 28. As this work was written by me expressly as a text-book for that part of my Lectures which relates to mechanism, I shall be necessarily compelled to refer to it repeatedly in the course of these pages.

teeth, and all of the same pitch, so that any two will work together. The quantity of these wheels, their pitch and numbers of teeth, must of course be determined by the nature of the machinery or models to which the system in question is intended to be applied. A few pairs of small bevel-wheels and mitre-wheels may be also provided, and ratchet-wheels, as well as a set of worm-wheels of different numbers of teeth, all of the same pitch, with worms to match. Pulleys, or 'riggers,' for belts or ropes, may be made of wood; but if tolerably large, as from 8 inches diameter upwards, are better, and look lighter, of cast iron, and may be procured at a moderate expense. (I have given more particulars of my own apparatus in the note.[1]) Every one of these revolving pieces must be accurately bored with a hole *one inch* in diameter, having a key-groove, and the boss faced in the lathe on both sides so as to reduce the thickness to *one inch*. The size of the hole must be exactly the same in all, because they may each be required in turn to take their place upon any one of a certain number of pieces, hereafter to be described, which are exactly

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[1] The wheels that I employ were furnished to me by the well-known firm of Sharp, Roberts, & Co., of Manchester. These gentlemen have an extensive assortment of patterns for small wheels, and will, I believe, for scientific purposes furnish castings of any that may be required. Their most complete set of numbers belongs to the size which they denominate *ten-pitch* (see 'Principles of Mechanism,' p. 59), in the peculiar nomenclature introduced by Mr. Roberts. This is equivalent to a pitch of $\frac{5}{16}''$ in the ordinary language of millwrights. Of this size, a set of wheels may be had containing every number from 12 to 100 inclusive, with the addition of 110, 112, 120, 127, 134, 138, 144, 156, 180, 200, and possibly some others.

Twelve-pitch and *sixteen-pitch* wheels (*i. e.* $\frac{1}{4}''$ and $\frac{3}{16}''$) may also be procured. The size of the former is exceedingly good for the construction of models, and perhaps better than the ten-pitch, because lighter; but unfortunately very few numbers of this size have been made (namely, 15 to 20, 24, 28, 34, 54, 59, 60, 108, 120); whereas the *ten-pitch* set is abundantly complete. The *sixteen-pitch* set includes wheels of all numbers from 16 to 60 inclusive, also 64, 68, 70, 72, 80, 90, 96, 120. These teeth are too small for the general purpose of lecture mechanism, but make very convenient wheels for some especial purposes. On the whole, the *ten-pitch*, although somewhat heavy, are by far the best, for they are strong enough to drive machines doing work, such as small lathes for turning metal, and the teeth are just large enough to be seen at a distance. The proportions of my framework are all adapted to carry ten-pitch wheels.

If the apparatus be intended merely to furnish the means of putting together certain examples of wheel-work trains previously selected and arranged for a given Course of Lectures, it will be obviously unnecessary to procure more than the actual wheels required for these machines; and the number of these wheels may be reduced to a very few by exercising a little skill in setting out the trains so that the same wheels may, as far as possible, be employed in different machines on successive days. But a complete apparatus should be prepared to meet any cases that may arise in the trial of new combinations and fresh machinery, and in the arrangement of change-wheel systems for actual work. To do this, at least one full set of the ten-pitch wheels, with duplicates of the most frequently recurring numbers (as 30, 60, 120), is required, to which should be added similar sets of the twelve-pitch and of the sixteen-pitch.

one inch in diameter.[1] The exact thickness of one inch is not so imperatively necessary. It is convenient in the set of spur-wheels, but in the others the thickness may vary according to their nature, within the limits determined by the length of the pieces which are to receive them.

(4.) Key-grooves are always made with their *sides* parallel; but the bottom of the groove may be either *parallel* to the axis or *inclined*. The first form is usually employed when the wheel is to be retained by a feather or pin projecting from the shaft or other piece to which it is to be attached. But when the wheel is to be secured to its shaft by a wedge, key, or *cotter*, as it is termed, the bottom of the key-groove must be inclined to the axis at the same angle as the wedge. As an inclined groove does not unfit the wheel for being used with a feather, provided the latter is not too prominent for the shallow end of the groove, it is better for our purpose to have the wheels furnished with inclined grooves, as they will then suit either method of fixing, as the case may be.

(5.) For mounting the above wheels, &c. on axes, to adapt them for use, I always prefer *stud-sockets*, if admissible. Fig. 8 (Plate I.) shows a section of the simplest form of stud-socket, of the dimensions adapted to the present purpose.[2]

The socket A B is of brass, one inch in diameter, to receive the wheels; it is provided with a shoulder (A) ($1\frac{1}{2}''$ diameter) at one end, and with a strong screw (B) and octagon nut at the other. It is three inches and a half long, and the plain part a little shorter than two inches; so that when two wheels are placed on it, the nut will screw them tight against the shoulder (the wheels being each an inch thick). A feather of the exact width of the key-groove is screwed against the plain part.

When only a single wheel is fixed on the socket, the brass collar, fig. 12, must be placed before or behind it, to enable the nut to act upon it. This collar is split, to allow it to pass the feather. The collars may be made of hardwood instead of brass, in which case they should be of larger diameter, to allow of a groove for the feather; and an assortment of such wooden collars of various thicknesses must be provided, for the stud-sockets are also required to receive wooden pulleys of various thicknesses, mahogany cam-plates, sheet-iron disks of various forms, &c.,

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[1] Machine-makers are so much in the habit of making the parts of their machines in great numbers, and also of replacing broken portions, that their arrangements are now successfully directed to making pieces so accurately bored alike that they may fit any one of a number of other pieces. Wheels that are too small to receive an inch hole must be bored with similar accuracy, with a hole $\frac{3}{4}$ inch in diameter, or $\frac{1}{2}$ inch, so as to fit pieces of those diameters respectively.

[2] Stud-sockets of various proportions are largely employed in manufacturing mechanism. I have merely put them into the forms most suitable to my own object.

any of which may be fixed by such collars, and at any distance from the shoulder A, by placing collars of proper size before and behind.

The socket revolves upon a stout stud C D, $\frac{5}{8}$ inch in diameter, with a shoulder or flanch C, at the back, of the same diameter as the base of the socket, and the stud is furnished with a strong screw and nut (E), behind, the screw being rather more than $1\frac{1}{2}$ inch long, so as to allow it to be fixed in a hole in a bar or other piece of frame-work to be presently described, the thickness of which is a full inch. The plain part of the screw close to the shoulder must be $\frac{5}{8}$ inch in diameter.

The front end (D) of the stud is pierced with a hole in which a pin is inserted to keep the socket in its place. As these sockets are continually removed and replaced on their studs, as well in the process of fitting up the apparatus as during the lecture, whenever it is necessary to take the wheels off, or otherwise separate the parts to facilitate the explanation of them, spring-pins (fig. 15) should be used. These are easily removed and replaced, are never liable to drop out, and will fit any hole.

The length of these sockets is quite sufficient for all ordinary purposes; but as in some cases rollers or wheels are required of greater projection, it is convenient to have one or two stud-sockets *six inches long*, and of the same dimensions as the above in every other respect.[1]

Rollers and other pieces, longer than the stud-sockets, may be mounted as shown in fig. 10. In this figure the stud and socket are precisely the

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[1] The sixteen-pitch wheels and the small pinions of the ten-pitch set, below 20 teeth, do not allow of an inch hole. They must be bored $\frac{3}{4}$ inch, and they are full $\frac{3}{4}$ inch thick. It is necessary, when these wheels are used, to provide stud-sockets for them differing from the above only in dimensions. These sockets are $2\frac{1}{2}$ inches long; diameter of studs $\frac{7}{16}$ths; diameter and length of the screw the same as for the larger studs, because they are required to fit the same holes in the frame-work.

The length of the socket allows one of the small wheels to be paired with one of the inch-bored wheels. But a loose collar (like fig. 12), $\frac{3}{4}$ inch bore and 1 inch external diameter, must be placed on the socket to receive it. One or two of these $\frac{3}{4}$-inch sockets may be made $4\frac{1}{8}$ inches long, and others $1\frac{1}{8}$ long. The latter are especially useful for wooden disks, levers, and other light pieces that would be preposterously mounted upon the inch-sockets.

But, for the purpose of combining small pinions with large wheels, I have sometimes found it necessary to employ a stud-sohket of the form (fig. 9), because the stud, if made small enough to carry a pinion bored only $\frac{1}{2}$ inch, is too weak to sustain the great wheel. This stud-socket was made for a train of clock-work, in which class of mechanism the pinions are always small and the wheels large. In this case the wheel had 138 teeth, and the pinion only 12, both of ten-pitch; the pinion admitted only of a bore of half an inch, and a stud small enough for a stud-socket of this diameter was manifestly too weak to carry the wheel, which was 14 inches in diameter.

same as that shown in fig. 8; but the socket is placed in the reverse position, having its nut downwards,[1] and the roller and other piece (A A) is turned with a hollow (c) at the top, sufficient to allow the spring-pin to be inserted in its hole. B B is a pinion (or any other wheel, &c.) by which motion is communicated to the roller from the rest of the mechanism.

(6.) There are several pieces, however, the forms of which do not readily allow of this expedient, and for which, if placed upon the socket in the position of fig. 1, the projecting nut and stud would be an equal impediment. Such, for example, is a handle which may be required to give motion to the first wheel of the train; a disk, the upper surface of which is required to be completely at liberty; or an arm with an excentric pin, &c. Although such pieces may be screwed to the top of a block similar to A (fig. 10), after it has been placed on the stud, it is better to employ the socket represented in fig. 13. This socket has the shoulder F F in the middle; the part below the shoulder is formed exactly like the previous sockets in the reverse position (fig. 10); but the part G, above the shoulder, is perfectly plain.[2]

This plain portion will receive any piece that is provided with a lateral binding-screw, such as the handle, fig. 34 (Plate II.), the flanch, fig. 32, which is made to carry excentrics or disks, or the coupling, fig. 37, which will serve to grasp any odd-shaped piece that can neither be bored with a central hole nor screwed against a flanch. These pieces are more fully described below. (See Arts. 30, 31.)

(7.) Another variety of stud-socket is shown in fig. 11. In this the stud is considerably shorter than the socket, and the latter is kept in its place during its revolution by a screw *a*, tapped into its shoulder, the end of which is engaged in a groove turned at the bottom of the stud. This allows the socket to revolve, but not to come off. Any piece which is of such a form as to allow of a short stem behind it can be fixed to this socket by inserting the stem in the vacant hollow above the stud, and securing it by a screw *b b*. Thus in the figure, a piece L is so shown, which is a section of a pinion so small as to forbid a hole being conveniently bored through it, in the direction of its axis, to fit it upon the various sockets already described. The pinion is therefore

[1] It is convenient that all the sockets should be fitted to their studs with cylindrical holes, instead of slightly conical holes. This allows the sockets to be placed with either end outwards at pleasure.

[2] The projection of the end of the stud may be reduced by the construction shown in fig. 14, namely, by substituting a flat screw and washer for the spring-pin. But this plan is more expensive, and does not allow of dismounting during lectures.

furnished with a stem M, which fits the bore of the stud-socket, and the stem, being inserted in the upper part of the socket, is secured by the screw *b b*.

Any wheel required to connect this small pinion with the train must be previously placed on the socket close to the shoulder, and also a collar between it and the nut.[1] This collar must have a hole bored in its side to admit of the subsequent insertion of the screw *b b*; for it is clear that the pinion or other piece (L, M) must be fixed in its place after the wheel has been secured to the socket by its nut.

Pieces that do not admit of being mounted for revolution on stud-sockets require other devices, which are explained in Chapter III. I shall in the next Chapter proceed to the framework by which the studs, as well as the whole of the machinery, are connected and supported.

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[1] This nut is not shown in the drawing, but is precisely similar to n in figure 3, and the screw-thread of the socket is seen just above *b b*.