CHAPTER II.

ON THE FRAME-WORK AND GUIDE-PULLEYS.

(8.) It will in the next place be convenient to show the nature of the frame-work by which the socket-studs described in the last chapter can be fixed in their proper relative positions, so as to cause the wheels, pulleys, or other pieces which revolve upon them, to gear properly together and form machines.

In arranging the parts of mechanism, it will be found that their axes of rotation may be required to be fixed in every possible position, whether horizontal, vertical, or inclined at any intermediate angle. Accordingly, when our rotating pieces have been mounted on stud-sockets, we must provide the means of fixing their studs in any of these positions, as the case may require, and also at the proper distances.

The most obvious way is to make a wooden frame for each especial machine, and to bore holes in the frame for the reception of the studs; care being taken to design the frame so that the rails of which it is composed shall present themselves at the proper angles and distances to receive the holes.[1]

This method I adopt when the machine in question is frequently wanted for use, or when its construction is so complex that the putting together of its frame by the more general system about to be described would consume too much time, and require too many pieces, to make the attempt worth while.

But even this simple method has a great advantage over ordinary models; for after the machine has been exhibited, the stud-sockets, wheels, and other parts of general use, can be removed, leaving the *peculiar*[2] parts by which most machines are characterized, and which may remain undisturbed, upon the frame-

[1] See Art. 43, and fig. 43, Plate II., for an example.

[2] Throughout this Essay I use the epithet *peculiar* to characterize all pieces and frames which are constructed for one object or model only, in contradistinction to those pieces or frames which are shaped to adapt themselves to a great many objects or models in turn.

work; and if the holes for the studs are carefully made, these, with their wheels, can be readily replaced when the machine is again required. But the quantity of such frames, if they were employed for every machine, would lead to serious inconvenience from their bulk, and they will be found perfectly unnecessary for the greater number of cases. In many examples, machines may be contrived in which the complex parts may be thus mounted in a small peculiar frame, and the simpler portions, together with this peculiar frame, be fixed upon a frame built up upon the general system. Thus we obtain a machine which, when put together for use, is large, and its acting parts spread forth so as to be distinctly visible to an audience; but which admits of being separated so that its peculiar frame and pieces may be stowed away for the next year's Lecture, while its general parts are available during the entire Course, as required.

(9.) The advantages of mounting the revolving pieces upon studs are various. When wheels are fixed to axes that are supported at or near each end, the frame-work becomes more complex; and if the wheels or any other parts lie between the two halves of the frame, they are liable to be concealed thereby. But when stud-sockets are used, the supporting piece of the frame is wholly behind or beneath, and thus leaves the revolving piece fully exposed to view; and the latter can also be readily taken off and replaced, if required in the course of the explanation. Again, the steadiness of rotation depends wholly upon the stud and its socket, and not at all upon the frame; and the stud-socket, which requires good workmanship, will serve for many machines, but the frame may be a mere deal board with holes in it, or other simple form, which, being of comparatively small cost, may be cut up or altered at pleasure.

(10.) I will now proceed to a system of framing which is built up of parts capable of being combined in various ways, so as to make frames for the support of the studs and other pieces in any relative position at pleasure. This may be called the *general system* of framing, in opposition to the *especial frames* above described. In the first place, for the purpose of carrying the studs firmly, and of readily fixing them in the various relative positions required, cast-iron *brackets* of six different forms are provided. These are all shown in Plate I., and are there indicated respectively as No. 1, No. 2, and so on. They will also be described in the following pages as Bracket No. 1, Bracket No. 2, &c.

Each bracket has a *head* A (see No. 1), bored with a hole $\frac{5}{8}$ inch diameter, and thus fitted to receive the screw (E, fig. 8) of any of the studs, which, as already mentioned, are of the above diameter at the shoulder; also a *sole* B, in the middle of which is a slit, full $\frac{3}{8}$ inch wide (or rather $\frac{1}{2}$ inch), to receive

the bolt or bolts by which the bracket is attached to the wooden or iron frame-work.[1]

The brackets differ from each other, as well in the direction in which the stud is fixed with respect to the sole as in the height of the stud above it. In No. 1, No. 2, and No. 3, the stud stands parallel to the slit of the sole, and its axis is at heights of 8, 5, and $1\frac{1}{2}$ inches respectively above the lower surface. In No. 4 and No. 5 the stud stands also parallel to the plane of the sole, but is at right angles to the direction of its slit, and at heights of 5 and $1\frac{1}{2}$ inches respectively. In No. 6 the stud stands perpendicularly to the plane of the sole.[2]

In each of these forms the stud may be fixed with its shoulder either on one side or other of the head of the bracket.

The higher brackets (Nos. 1, 2, and 4) are also provided with bolt-slits in the upright face, for the convenience of fixing other pieces, as will presently appear.

(11.) The brackets are fitted up for use, as follows, by fixing them to wooden or iron stands or frames. For the purpose of uniting the brackets to these frames, as well as the parts of the frames to each other, I employ bolts of the kind termed *coach-bolts*. These have a circular and convex head, below which the shank is made square for a short distance, and then continued as a strong screw with a square nut. The shank is $\frac{3}{8}$ inch square, and the slits in the brackets are adapted to receive it: a washer must be placed under the nut, and if the head of the bolt bears against a wooden frame, another large washer must be also placed under this head, but is unnecessary if the head bear upon the sole of the bracket. A key or spanner must be provided, to screw up the nuts. Thumb-screws, or fly-nuts, as they are called, may be employed,[3] but I greatly prefer the plain nut for its simplicity and firmness, and because it looks neater and more engine-like, and is besides cheaper, as the coach-bolts can be had ready-

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[1] A mathematician will perceive that I have so designed these brackets, that supposing their soles to be fixed on a plane horizontal or vertical surface, with the slits parallel to each other, the different forms give the power of placing the studs parallel to the three axes of co-ordinates.

[2] The dimensions of the brackets are,—sole, $6'' \times 2\frac{1}{2}''$; diameter of head, $1\frac{1}{2}$ inch; thickness of head, $\frac{9}{10}$ inch; thickness of sole, $\frac{5}{8}$ inch; thickness of upright, $\frac{1}{2}$ inch. The patterns of these brackets and of the rectangle (Art. 15) are in the hands of Messrs. Holtzapffel, 127, Long Acre.

[3] Bolts with fly-nuts are employed in fig. 45, Plate III. (Art. 45,) to fasten the two No. 3 brackets to the bridge. But the position of these brackets, from the nature of the apparatus, may require to be changed, to adjust their distance for different proportions of the curves; and whenever such adjustments are required, fly-nuts are of course convenient and appropriate.

made in the shops. An assortment must be kept of various lengths, which I will indicate as their uses occur.[1]

(12.) The wooden frames which constitute the bases of the machinery are of various kinds, but all constructed on the principle of providing a number of slits, $\frac{3}{8}$ inch wide, for the reception of the bolts by which the soles of the brackets are attached to them. Fig. 16 (Plate II.), which I term a *slit table*, is the simplest form: it consists of four bars of deal, each 2 feet long, $1\frac{1}{4}$ inch broad on the upper face, and $2\frac{1}{2}$ inches deep, arranged so as to leave a space of full $\frac{3}{8}$ inch between each. It is supported on two feet, so as to raise the bars a convenient height, for access to the nuts below, and allow room for overhanging wheels, &c. Each foot is, as the drawing shows, notched on the upper edge to keep the bars in their places, and united to them by a single bolt, which passes through the whole. Thus we have a table about $6\frac{1}{2}$ inches wide and 2 feet long, upon which the brackets may be set so as to bring their studs into any required relative position; and the soles of the brackets being laid transversely to the slits, the slit of the sole is sure to intersect one or more of the slits in the table, so as to allow a bolt, or two if required, to be passed through and secured, the nut being placed upwards or downwards, as convenience may dictate. The 'slit table' is shown in use in fig. 42 (described below in Art. 42).

The mode of arranging a simple train of wheel-work, consisting of wheels and pinions with parallel axes, will be understood from the following diagram, in which A, B, C, are the wheels, *a*, *b*, *c*, the pinions with which they respec-

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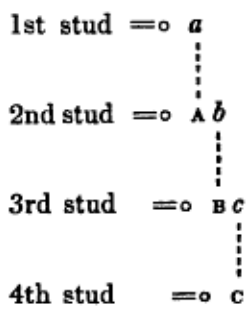
[1] Bolts unite pieces more firmly than the clamps which are most commonly resorted to for apparatus; but bolts require holes or slits to be provided in the pieces which they must necessarily pass through. On the contrary, clamps unite pieces that are not so pierced. Occasionally, therefore, clamps must be employed. Fig. 7 represents a form that I have adopted, which has the advantage of not bruising the pieces to which it is applied. It consists of an L-shaped piece (H), the long leg of which is formed into a strong screw, and provided with a large fly-nut. The nut acts upon another L-shaped piece (K M), which has a hole through which the screw passes *freely*, so as to allow this piece to take its bearing firmly by the leg M upon the thing to be clamped, and by the other leg K upon the back of the first piece H. I employ two sizes of these clamps, differing only in the extent to which the jaws H M may be opened. The jaws and flat part of the backs are $\frac{1}{4}$ inch thick and $\frac{5}{8}$ inch wide; screw about $\frac{4}{10}$ inch diameter. The range of motion is of course determined by the length of the plain part and of the screw. In the smaller size the opening of the jaws ranges from $1\frac{1}{2}$ to 3 inches, and in the larger from 3 to 6 inches. The inside length of the jaw H is 2 inches. A diminutive form of this clamp is also very useful for clamping paste-boards to thin frame-work, or drawing-paper on drawing-boards. Its opening ranges from $\frac{1}{2}$ to 1 inch. It is $\frac{1}{10}$ inch thick and $\frac{4}{10}$ inch wide, and the inside length of H is $\frac{4}{10}$ inch. Besides the plain coach-bolts, hook-bolts and T-bolts are sometimes required, as well as a few fly-nutted bolts. (See Arts. 32 and 46, and figs. 48, 49, Plate III.)

tively gear; the wheel and pinion that occupy the same stud-socket being set in the same horizontal line, and the characters =o indicating the place of the bracket-sole and head respectively. The diagram thus represents a plan of the relative positions of the mechanism upon the slit table.



The 1st stud carries a pinion *a*, which gears into a great wheel A, fixed on the 2nd stud; and as the pinion and the wheel should be set close to the shoulders of their respective stud-sockets, the two brackets will stand with their faces in the same line. But the pinion *b*, in front of it, gears with the great wheel B, which is close to the shoulder of the 3rd socket, and thus the 3rd bracket will be set a little in advance of the 2nd bracket. Similarly the 4th bracket will be a little in advance of the 3rd, and thus all the brackets, except the first, will be set in a slanting direction. Their great wheels will be as close as possible to the head of the bracket, thus laying the least strain upon the stud; and as each stud is mounted upon an independent bracket, it can be shifted about and set in any relative position to the others that will best suit the pitching of the wheels, or the nature and thickness of any other revolving pieces that may also be mounted upon the stud-sockets. As the wheels are all placed behind the pinions, they do not conceal them.

(13.) The choice of heights at which the studs may be fixed, given by the different forms of the brackets, is not always sufficient to suit all arrangements; therefore an assortment of wooden blocks is required, termed *sole-blocks* (fig. 17). These are of various thicknesses, and their breadth, width, and slit correspond exactly to those of the bracket-soles. Thus the height of every bracket may be adjusted as required.[1]

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[1] The thicknesses provided should be $\frac{1}{4}''$, $\frac{1}{2}''$, $\frac{3}{4}''$, $1''$, $2''$, $3''$, and $4''$. In practice, it will be rarely found necessary to employ sole-blocks; the choice of heights given by the brackets and adjustable frame-work is usually sufficient, as the smaller adjustments required for pitching toothed-wheels or for stretching bands can all be effected by the changes of horizontal position which the nature of the frame-work admits of almost indefinitely.

It may at first appear that the different heights of the studs might be adjusted by forming the bracket-head with a slit instead of a hole for the reception of the screw of the stud. But I find that if a stud-screw be inserted in a slit, the last turn of the nut in securing it is sure to disturb it from its position by the wriggling motion which it gives to the screw. The shank of the screw being of course made square (or at least flattened on opposite sides) to fit the slit, must necessarily have a little play to allow of sliding the stud into the required positions, and this play permits sufficient torsion to produce the effect above described, which is exceedingly vexatious. For example, if a toothed-wheel be mounted on a stud, and the stud placed in a

(14.) Slit tables of similar construction to fig. 16 may be made, if required, of different dimensions and numbers of bars; but I find the actual form and dimensions of this example the most convenient; and for machines that require larger or more comprehensive frames, the following more general system is better.

A set of wooden bars is in the first place provided, which are screwed together in pairs, as in fig. 20. The bars of each pair are united by strong screws passing also through small blocks of hardwood (*a* and *b*), which fix the bars at full $\frac{3}{8}$ inch asunder, so as to allow the coach-bolts to pass between them. Such a pair of bars I term a 'bed,' from its similarity to the bed of a lathe, which in like manner consists of two parallel cheeks of wood, between which the bolts pass by which the poppet-heads are secured. The bars of my beds are all of the same depth, namely, $2\frac{1}{2}$ inches, and their breadth varies from $1\frac{1}{8}$ to $1\frac{1}{2}$ inch, according to their length. The beds are of the various lengths of 1′ 6″, 2′, 3′, 4′, 5′, 6′, and 10′.[1] It is convenient to have four or more of the three first lengths and two each of the remainder. I make these beds and frames of deal for cheapness and lightness, but possibly beech or birch might be better, as the repeated screwing and unscrewing of the bolts is apt to indent the soft fibres of the deal. This is diminished by using large washers.

It may sometimes be necessary to employ triple instead of double bars for the beds, in cases where two bolts are required to hold a piece the slit of which lies transverse to the slits of the bed, and which happens to be liable to great strains.

(15.) Fig. 19 represents a cast-iron 'rectangle' employed for supporting and connecting the beds. Its faces are $2\frac{1}{2}$ inches broad (the same as the bracket-soles), their length 6 and 9 inches respectively, and thickness $\frac{5}{8}$ inch. Each face has a bolt-slit, as shown. Three or more pairs of these rectangles should be provided, for they are not only applicable to the support of the beds, as shown in figs. 27 and 39, but are useful in forming stands to which brackets or other pieces may be fixed, and also in constructing other parts of frame-work, as shown in fig. 47 (Art. 46).

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slit in the proper position for pitching with another wheel, this small disturbance of position destroys the pitch. The same effect does not take place when two slit pieces, such as the sole of a bracket and the slit table, are united by a bolt; for the position of the two pieces is secured by the contact of their surfaces, and the wriggling above described only affects the bolt. It will be seen too that the surfaces in contact are much greater than when the shoulder of the stud rests upon the edges of a slit, as in the former case.

[1] In the following descriptions, for conciseness sake, a bed 2 feet long is termed a *two-feet* bed, and so on.