CHAPTER III.

ON THE SHAFTS AND TUBE-FITTINGS.

(23.) HAVING now explained the principal parts of the frame-work, I will return to the arrangements of the revolving mechanism.

I have already stated the advantages of mounting these parts for exhibition, as far as possible, upon studs; this, with a little contrivance, may be done to a very great extent. No doubt a long stud is liable to bend, and its diameter being necessarily greater than those of the pivots of an axis or shaft supported at the ends, introduces greater friction. But the forces and resistances of the machines we have to deal with in the Lecture-Room are rarely of sufficient magnitude to occasion inconvenience on this score. Nevertheless there are combinations in which shafts must be employed, and I will now explain the manner in which I have arranged them, in conformity with the system of frame-work.

When the pivots or necks of shafts are sustained by two 'plummer-blocks,' 'pedestals,' or other supports independently attached to the frame of a machine as usual, great inconvenience necessarily arises from the difficulty of fixing these pedestals so that the axes of their holes shall coincide with the direction of the shaft; for as every practical mechanist knows, the holes in the pedestals which receive the pivots or journals may separately fit the latter perfectly, and yet it will be found that when the pedestals are to be screwed to the frame, a great deal of careful fitting and adjustment is required in putting them together; otherwise the direction of their holes will be twisted, so as to set the shaft perfectly fast, and require the insertion of wedges or bits of paste-board, or careful filing of the seats against which they are fixed. Processes of this kind are plainly out of the question in putting lecture-machinery together.

Such shafts as are wanted must therefore be fitted each in its own carriage to which the pedestals or bearing-holes are permanently fixed, so that this carriage may be bolted to the frames already described when the shaft is required to take its place in a train of machinery; or else the pieces which sustain the ends or necks of the shafts must be so contrived as to obviate the necessity of the above-described troublesome adjustments.

(24.) Fig. 35 represents a cast-iron carriage adapted to our system. It carries a short shaft, 1 inch in diameter, and 5 inches long between the bearings. The latter are fitted with caps, with binding-screws, and oil-ways, so that the shaft is very steadily mounted in the most complete manner. The shaft is not intended to receive revolving pieces between the bearings, and therefore does not require to be dismounted. But the ends upon which the wheels, &c. are to be fixed project, the one 2 inches and the other 3 inches. A flat fillet is filed upon these plain parts, and thus any large wheel or rigger, provided with a binding-screw in its boss, or any other piece similarly fitted with bindingscrews, as the handle (fig. 34), or the flanch (fig. 32),[1] may be attached to the shaft. But the toothed-wheels and pulleys described above (Art. 3), which are all bored with an inch hole with key-grooves, do not readily admit of the addition of a binding-screw. For these the 'lengthener' (shown in section, fig. 36) is provided. This is made of iron, and has a socket with a bindingscrew by which it can be fixed to the end of the shaft. Its left-hand portion is 1 inch diameter, and has a feather or a pin to suit the key-groove of the wheel, and a screw and nut by which to fix it in its place against the shoulder.

The 'coupler,' fig. 37, is also intended to fix short pieces of inch-shaft to the ends of the carriage shaft, in order to lengthen them, if required, and will also serve to attach disks or other pieces that admit of a short neck or stem of hardwood, 1 inch diameter, being fixed to their backs.[2]

The cast-iron carriage has four bolt-slits, two of which are seen in figure 35. It may either be bolted to the beds, &c., or directly to the stool at any part most convenient. It is strong enough to carry a small fly-wheel of 2 feet diameter, like those employed for five-inch lathes. In this case the carriage may be bolted to one of the top beds of the stool; for example, midway between B and C, fig. 24: the

---

[1] See Arts. 30, 31, for the description and use of these.

[2] The most complete way of arranging the end of the carriage shaft is to cut a square-threaded screw upon it which does not interfere with its cylindrical form, and therefore allows an inch-bored wheel, or two, to be fitted steadily upon it, and pressed against its shoulder by the nut. There may be a flat place filed upon this screw, which will not disturb its action; or better, a groove sunk in it for the reception of a feather that will thus adapt itself to the key-grooved wheels, and may be removed if it be required to fix a wheel which is simply bored and fitted with a binding side-screw. The square-threaded screw should stop short of the shoulder, to leave a plain part for the binding-screws to act upon, which might otherwise bruise the thread. When a shaft is thus provided with screws and nuts, its shoulders must be both outside, not both together as in the figure. One carriage may be fitted up with this kind of shaft, and another with the plain shaft.

fly-wheel, which must be provided with a strong binding-screw, should be placed on the inner end of the shaft, so as to revolve within the stool. The handle (fig. 34) being then fixed on the outer end of the shaft, will be at a convenient height for the hand, and a useful hand-wheel is thus arranged, by which motion may be given by an assistant to the larger class of machines, which are built upon the stool or fixed on a separate frame; or a treadle may be fixed below, the link of which may act upon a shorter handle-arm. If more convenient, the wheel may revolve outside the stool, and the handle or crank-arm within it.

One or two shafts in carriages of this description are necessary for strong work, and are applicable to all cases in which the limited length of the shaft is no inconvenience. But the most comprehensive method of arranging shafts is that which is described in the next Article.

(25.) The shafts, in this general method, are plain turned iron rods of the several diameters of 1″, $\frac{3}{4}$″, $\frac{5}{8}$″, $\frac{1}{2}$″. For simplicity, however, I will at first confine the description of the arrangements and appendages to the $\frac{3}{4}$-inch diameter, and apply them to the other diameters afterwards. The lengths of these may be 3′, 2′, 1′, and 7″. By way of pedestals to support and guide them in their rotations, I employ pieces termed *tube-fittings*.

The *tube-fitting* (fig. 29) I make of gun-metal or brass, in one piece. It consists of a tube M N, 2 inches in length, bored to fit the $\frac{3}{4}$-inch shaft, and 1$\frac{1}{4}$ inch in external diameter. The back of this tube presents a flat surface parallel to the bore, from which projects a stem P, $\frac{5}{8}$ inch diameter and 2 inches long, having a strong screw upon it, provided with a nut (omitted in the drawing). This stem and nut serve to fix the tube to the heads of the brackets, which, it will be remembered, are bored with a $\frac{5}{8}$-inch hole, and the direction of the tube may thus be fixed at any required angle in the plane parallel to the face of the bracket. Also, the bracket can be shifted round the bolt which fixes its sole to the frame, and the axis of this motion is perpendicular to the stem of the tube; so that, by combining the two motions, the tube can be fixed in any required direction.[1]

Fig. 39 is intended to show the manner in which shafts may be mounted upon this system. It represents a frame carrying two shafts, the lower of which (A) is horizontal and parallel to the bed, and the upper (B) inclined both horizontally and vertically. Each shaft is carried by a pair of tube-fittings in brackets. The frame is composed of a 3-feet bed (C) upon rectangles (D, E). The tube-fittings of the lower shaft are carried by No. 3 brackets (F, G), bolted to the upright faces of the rectangles. Thus each tube can swivel about its *vertical* stem and the *horizontal* bolt of the bracket, and the troublesome adjustment described in Article 23 is

[1] See 'Principles of Mechanism,' p. 280.

wholly avoided; for when the shaft is in its place, and the nuts of the stems and bolts moderately fast, the tubes of themselves are compelled to take their places in the line of direction of the shafts, and the nuts may be then screwed fast.

The upper shaft (B) shows how an inclined position may be given. In this instance the higher end of the shaft has its tube-fitting attached to a single No. 1 bracket (K), and that of the lower end to a No. 3 bracket (H), and these brackets are also so disposed as to place the shaft across the direction of the bed horizontally. In similar ways any required angular position may be given to a shaft with respect to the frame, and the tube-fittings will always accommodate themselves to the line of the shaft, as above explained.[1]

In selecting the proper brackets for any required position, it must be remembered that the adjustability of the *tube to the line of the shaft* depends upon the former having two axes of adjustment (namely, its stem and the bolt which fixes the bracket-sole), which must not be parallel to each other, neither must the shaft be parallel to the bolt.

It follows, therefore, that the bracket No. 6 is not applicable to the support of a tube-fitting, because its bolt would be parallel to the stem of the tube. Also, no form of bracket can be applied to the support of a vertical shaft, if its sole be placed horizontally, because thus the bolt and shaft become parallel. Therefore, when it is required to support a vertical shaft by a tube-fitting, the frame must be so arranged as to place the bracket-sole vertically.

(26.) To prevent the endlong motion of the shafts, which are mere plain cylinders unprovided with shoulders or necks, rings must be employed. This device is usual in manufacturing mechanism when a shaft requires to be often taken out for cleaning or adjustment. Two rings, fitting the shaft accurately, and secured upon it by binding-screws, are attached on each side of one or other of the pedestals, or tubes, if the latter be employed; or, if more convenient, they may be fixed either close to the inner sides of the tube, or to the outer sides.[2] It is plain that in either

---

[1] The tube-fitting was suggested to me by a somewhat similar method of supporting shafts in some machines at Manchester. In these the shaft passed through a short cylindrical tube of metal or hard-wood. The tube was inserted in an iron ring which had a tail attached to it, tapped with a screw and nutted. This tail being passed through a slit in the frame-work, and the nut put on and screwed up, the tube was grasped and pressed against the frame, and the slit allowed sufficient play to enable the tube to settle itself in the direction of the shaft, but by no means the universal adjustment afforded by the form I have been led to adopt.

[2] *a*. ●. *b*. *c*. P. *d*.

In this diagram, if the line represent a shaft, and O P the place of the tubes, it is clear that we have the choice of four positions for the two rings; namely, (1) at *a b*, (2) at *c d*, (3) at *b c*, (4) at *a d*.

of these four manners the shaft will be free to revolve, but prevented from sliding endlong. If a wheel or other piece be fixed on the shaft close to either tube, it will manifestly render one of the rings unnecessary.

It will be seen that the system of mounting shafts just described is well adapted to our purpose, because it leaves us at liberty to place the bearings at any convenient distance, and to choose any required projection of the free ends of the shaft. A narrow flat fillet may be filed along the shaft, to receive the pressure of the binding screws by which the rings and the other pieces about to be described are attached to it. This fillet will not impede the rotation of the shaft in the tubes, and it serves to receive the small burrs or bruises which the screws are apt to produce when repeatedly applied, and which would disturb the smoothness of the rotation if allowed to be impressed on the cylindrical surface.

(27.) Some or all of these shafts should have deep conical centre-holes at their ends.[1] This will enable them to be mounted occasionally to run between *centre points*,—a method which has much less friction than the tube, and is also useful for vertical shafts. In the latter case the lower end of the shaft may rest upon a point, and the upper be supported by a tube-fitting, especially if the upper end be required to run free,—to sustain a disk, for example. (In fig. 47, Plate III., such a vertical shaft is shown at A.)

One or more pairs of pointed centre-screws of steel must be therefore provided, each having two nuts, and the external diameter of the screw being $\frac{5}{8}$ inch. The screw will thus fit the holes in the heads of the brackets, and may be secured by a nut on each side of the head. This obviates the necessity of tapping the hole to fit the screw. The head of the screw should also have a conical sunk recess to receive the point of a revolving shaft, if required; in which case it must be placed in the bracket so as to present the head to the shaft. A pair of brackets thus provided with centres must be bolted to a bed or to any convenient frame-work, so as to receive the shaft, and the screws may be adjusted by turning the two nuts simultaneously, until the shaft is found to revolve with proper freedom.[2]

(28.) The toothed-wheels, pulleys, &c., which, as above described, are bored with an inch hole, are fixed to the shafts by the intervention of a piece termed an *adapter*, shown in section in fig. 33. This is bored with a $\frac{3}{4}$-inch hole to fit the shaft, upon any part of which it can be secured by the binding-screw. Its external diameter is one inch, and it has a shoulder below, through which the binding-screw

[1] If each shaft is turned in a single length between centres in the lathe, the original centre-holes will answer the purpose; but if they are cut from one long rod, the centre-holes must be made afterwards.

[2] In fig. 46 the shaft B of the swing-frame is supported by centre-screws of this kind. If it be required to support a shaft which has small pivots at the end, a pair of small tube-fittings may be used.

is tapped, and a nut and screw at the opposite end. Its length is sufficient to receive one wheel. To prevent the wheel from slipping round, a feather may be fixed to the adapter; but as one wheel only is placed upon it, the feather need not be prolonged as in the stud-socket, upon which two wheels are usually mounted; and, in fact, a pin of sufficient diameter, driven tight through a hole bored in the shoulder of the adapter, is sufficient, and is simpler.[1] Three or four of these adapters are required, some of which should be longer than the above, to receive pulleys or riggers that may be thicker than one inch, or two wheels, if need be.

(29.) Long rollers or cylinders, however, are better secured to the shaft by boring a ⅝-inch hole through them which will fit the shaft. The roller must then be placed upon the shaft between two shaft-rings, one or both of which has one or two stout pins fixed into its edge, so as to lie parallel to the shaft (as shown in fig. 30). These pins being inserted into corresponding holes in the roller, and the shaft-rings secured to the shaft by their binding-screws, the roller will plainly be completely united to the latter.

(30.) The *flanch*, fig. 32 (shown in section at A and in front at B), is useful to fix pieces to the shaft in cases where the nut and shoulder of the adapter, by projecting on each side, may be in the way. This is especially the case at the free extremity of a shaft. The flanch is made of cast iron or of brass; it is bored to fit the shaft, and has a projecting boss behind, with a strong binding-screw to secure it thereon: the face is turned flat, and about 3 inches diameter. Three holes are bored at equal angular distances near its margin, and a fourth opposite to one of the former, as shown in the figure. These four holes are tapped to receive strong screws.

Small excentric pins, for giving motion to the rods of link-work, &c. may be attached to the flanch by these screws, as is shown in the figure. The pin *k* is carried by a slit piece *l m*, which admits of an adjustment that may give it any desired excentricity, from zero to a radius a little greater than that of the disk. For greater distances another pin may be provided, fixed to the extremity of a longer looped piece.

By means of these screws also, pieces of wood, such as large disks, cam-plates, riggers, excentrics, and so on, may be fixed to the flanch, and thus to the shaft. Generally the *three* holes will be preferred for this purpose. The *two* opposite holes are adapted to fix bars carrying excentric pins, or any similar contrivances.

[1] I sometimes employ a screw tapped into the side of the adapter, the head of which is filed square to fit the key-groove of the wheel. This has the advantage that it may be removed if the wheel be required to slip round. A similar screw, with an oblong head, may be used for the stud-sockets; if tapped into the plain part of the socket, with its centre one inch from the shoulder, it will catch both the lower and upper wheel.

If the projection of the screw-heads be objectionable, they may be sunk below the surface of the wooden disk; but if the latter be required to be attached to the extreme end of a shaft in such a manner as to leave its outer surface perfectly unbroken and smooth, three pins must be fixed to its inner surface, so as to pass through the three holes in the flanch; and the pins being tapped at their extremities, nuts and washers will attach the disk to the flanch. Such a disk is sometimes required to receive drawing-paper in mechanism for tracing curves, and in such cases screw-holes or other disturbances of the surface would interfere with its action. A disk may also be fixed to the end of a shaft by a stem fitted to the coupler, fig. 37, as explained in Art. 24.

(31.) The *lever arm*, fig. 34, has a boss at one extremity, bored to fit the shaft, and having a binding-screw. The arm is bored with several holes, or else made with a slit. It is intended to receive either a wooden handle (B), as in the figure, which converts it into a winch for giving motion to the models, or else pins (A or C) for link-work motions. The connecting-rods of the latter may be made of wood. The long pin (C) combines the office of a handle and of an excentric pin, as will be more apparent below, in the explanation of fig. 40, in which these lever arms are shown in use.

The flanch and its appendages (fig. 32), the lever arm (fig. 34), the adapter (fig. 33), the lengthener (fig. 36), and the coupling-tube (fig. 37), may all be employed in the stud-socket system by fixing them to the stud-socket, fig. 13, as already mentioned above (Art. 6). But for this application they will require to be bored with an inch hole, if the stud-socket be of an inch diameter; whereas the set of apparatus just described is adapted for ¾-inch shafts, and therefore bored with ¾-inch holes.

(32.) Here it may be remarked, once for all, that in any system of pieces which are required to fit together in various combinations, it will necessarily follow that the larger machines will appear too light and the smaller too heavy; for as the transverse sections of all the pieces of the same kind in a common system must be the same, to allow of mutual fitting, while the lengths may be and are different, the longer pieces will of course tend to a light and weak proportion, and the shorter to a clumsy and stronger proportion.

This objection is not a very serious one in the ordinary purposes to which the plan is applied; for the parts of all machines, whether they be originally small or large,—watches, mouse-traps, or steam engines,—require all to be constructed and exhibited upon a scale that will make them visible at a distance, in the same manner as the draughtsman delineates the small parts of mechanism on an enlarged scale, and reduces the larger ones. But in a complete apparatus the proper remedy is to establish two or three definite sizes, in every one of which a set of the parts above described must be made. These sizes I have, in fact, already indicated. Thus there should be an *inch set*, in which the wheels are bored with an inch holen the stud-sockets an inch diameter; the shafts $\frac{3}{4}$ inch diameter, with their tube-fittings and apparatus to suit, as in the description given above: also a $\frac{3}{4}$-*inch set*, in which the wheels being bored $\frac{3}{4}$ inch, the stud-sockets are $\frac{3}{4}$ inch diameter, and the shafts $\frac{1}{2}$ inch diameter, with their proper apparatus. These two sizes are sufficient for most purposes. A still smaller set, adapted to thin wheels cut in brass plate, might be sometimes useful.

For some machines of the larger class the inch-bored wheels may require to be *keyed* upon shafts 1 inch diameter for greater *strength*, instead of being fixed by means of adapters upon $\frac{3}{4}$-inch shafts; and therefore a shaft or two of 4 feet and 3 feet length, with rings and tube-fittings, should be provided. Larger diameters of shafts than these are beyond the requirements of the system; but short shafts of $\frac{5}{8}$ inch diameter are useful, because they fit the $\frac{5}{8}$-inch holes of the bracket-heads, and are otherwise of a good proportion.

Thus we have the four diameters of shafts mentioned at the beginning of Art. 25; namely, 1″, $\frac{3}{4}$″, $\frac{5}{8}$″, $\frac{1}{2}$″, in each of which sizes an assortment of lengths must be kept, and one or more pairs of tube-fittings, shaft-rings, and adapters, to each size, and there must also be a handle to each. Separate flanches are not so necessaryn a flanch bored one inch will fit the stud-socket, fig. 13, or an inch shaft, and may also be fixed to $\frac{3}{4}$ inch diameters by means of a split collar (fig. 12) which is thin enough to yield to the binding-screw, and enable it to grasp the shaft. Similarly, a flanch bored $\frac{5}{8}$ inch will also suit a half-inch shaft by means of a split collar.

With respect to the frame-work, it will be seen that I have provided cast-iron brackets for the larger pieces and wrought-iron loops for the lighter pieces. The beds must necessarily be of the same depth in all the various lengths, in order to preserve the level of their surfaces when two or more of different lengths are employed side by side. But to diminish the clumsiness of the short ones, or weakness of the long ones, their thickness is varied from an inch and an eighth to an inch and a half, according to their length. Also, the lighter form, shown in fig. 27, is employed for small pulleys, rods, levers, or other matters that do not require the cast-iron brackets.[1] A set of beds of

[1] These small beds are 4 feet long, $\frac{7}{8}$ inch thick, and each bar of the pair $1\frac{1}{8}$ inch on the face, and $\frac{1}{2}$ inch aparto small bolts being kept for the purpose of connecting them. The intermediate size may have their bars $1\frac{1}{8}$ inch thick and $1\frac{3}{8}$ inch deep, being in other respects exactly like fig. 20, and of the lengths 2′, 3′, 4′.

an intermediate section may be made, if thought necessary. Bolts also must be kept assorted in sizes, they being the universal implements of connexion in this system.[1]

(33.) There are many cases in the fitting up of machinery in which it is required that the two ends of a shaft should be free to receive revolving pieces, but for which a long shaft supported on two bearings is not necessary. A short shaft supported by a single tube-fitting fixed in the head of a bracket may be used for these purposes; but the pressure of the nut of the stem is not always sufficiently powerful to prevent the stem from slipping round in the head of the bracket, so as to disturb the position of the shaft. It is therefore necessary to have a binding-screw in the head of the bracket, (as shown in No. 6, Plate I.) which effectually secures the stem from this twisting. One or two of the brackets of each form should be thus provided with stout bindingscrews[2] in the head, which are also useful for fixing cylinders or other pieces in the hole, as shown in fig. 41. (See Art. 37.)

(34.) An example of the employment of short shafts in single tube-fittings is given in fig. 40. This represents a model of the arrangement of link-work

---

[1] I have already stated (Art. 11) that the principal frame-pieces of the system are all to be united by coach-bolts $\frac{3}{8}$ inch square. Having now explained these frame-pieces separately, I will give some useful details respecting the different *lengths* of bolts required, which are of course determined by the respective thicknesses of the pieces they have to pass through. Now the bolts are employed to unite, (1st,) brackets to rectangles or other bracketse (2nd,) brackets or rectangles to beds or stools; (3rd,) beds to stools. The actual thicknesses of each of these several combinations are, (1st,) $1\frac{1}{2}$ inch; (2nd,) from $3\frac{1}{4}$ to $3\frac{3}{4}$ inches; (3rd,) $5\frac{1}{2}$ inches. Thus about four lengths of bolts are necessary, in each of which the bolt must be so long as to allow of a washer at each end and a good projection of the screw. Occasionally longer bolts than the above are required; and for putting together smaller sized frame-work an assortment of bolts with smaller shanks than the $\frac{3}{8}$-inch coach-bolts are exceedingly usefule for example, they may be $\frac{1}{4}''$, $\frac{1}{8}''$, and $\frac{1}{16}''$ square, and (the smallest especially) may be provided with fly-nuts.

Messrs. Fenn, of Newgate Street, now keep for sale a very useful kind of small steel and brass bolts, the former $\frac{1}{16}''$ diameter, the lattere $\frac{1}{8}''$ diameter, of various lengths, and with hexagon heads and nuts. I have been for many years in the habit of keeping ready for use steel and brass screws of two or three of such small sizes, some having slit beads for the screw-driver, others milled heads and nuts to snit, and also taps to suit when the screws are used for connecting pieces that require a tapped hole. Much time is in this way saved in the construction or alteration of experimental apparatus. As a general principle in designing apparatus, it is better to connect parts by bolts and nuts than by screws tapped into holes, especially if the parts have to be frequently taken to pieces or are likely to be altered.

[2] I prefer inserting *two* binding-screws in the bracket-head, at an angle of about 60° apart, because two screws will gripe a piece of considerably less diameter than the hole, which one screw will not do, unless the opposite side of the hole be filed into the form of a V trough.

by which two parallel axes can be so connected as to revolve simultaneously. It is the element of mechanism which I have explained at p. 187 of my 'Principles of Mechanism.' Two No. 1 brackets are bolted to a 3-feet bed, which is sustained by feet. Each bracket carries a *tube-fitting* with a short shaft, $\frac{3}{4}$ inch diameter (or less, if such be provided), and 5 inches long. A lever arm (like fig. 34) is screwed to each end of each shaft, care being taken that the corresponding arms are of exactly the same length. I employ a pair of $6\frac{1}{2}$ inches long on one side, and a pair of $4\frac{1}{2}$ inches on the other. These arms are set at right angles to each other, or nearly so, and a pin (like A, fig. 34) is screwed into three of them, and a longer pin (C, fig. 34) into the fourth. Two wooden rods are provided with a hole at each end, to suit these pins, and bored at *exactly the same distance*, which may be about 2 feet 6 inches. The brackets are fixed so that the axes of the tubes shall also be set at the same distance as these holes. When the rods are in their places, as shown in the figure, the final adjustment of this distance is very easily made, as a few trials readily point out the necessary changes.

The long pin serves as a handle to give motion to the machine. When the two rods are in place, the motion is smooth; but by taking off one of them, it can be shown that the system is then capable of two kinds of motion (as shown in my 'Principles of Mechanism'), and that the change from one to the other can only be made at the dead points, &c.

(35.) Another way of arranging these short shafts is to have brackets like No. 2, Plate I., but in which the head is larger, so as to admit of an inch hole being bored through it. Thus an adapter can be fixed in this hole by its nut, and a short $\frac{3}{4}$-inch shaft will revolve in it, and may have wheels, levers, &c. fixed to its free ends at pleasure.[1]

The wrought-iron piece, fig. 21, is also useful for this object and similar ones. It is made $\frac{3}{8}$ inch thick, has a hole one inch diameter at the end, and a slit, $4\frac{1}{2}$ inches long and $\frac{3}{8}$ths broad, to receive the bolts by which it may be attached either to the wooden framework or to bracket-heads, &c. The inch hole is destined to receive an adapter of an inch external diameter, which may be screwed fast to the iron by its nut, by interposing a collar of wood or brass of sufficient length. As the adapters are bored of the sizes of the shafts, we have thus a convenient tube within which a short

[1] If the holes in the head of the ordinary form of bracket were carefully and cylindrically bored, $\frac{5}{8}$-inch shafts would revolve in them for this purpose; but holes in metal are usually made slightly taper or conical by the action of the rimer which is employed to enlarge the hole made by the drill and adjust it to the proper size. The holes are thus rendered unfit for the steady rotation of a short shaft.

shaft can revolve, being retained endlong, as above, by rings or any piece that may be fixed to it, and tho iron can be bolted to the frame-work in any required position.[1]

(36.) It may happen that a number of pieces are required to turn freely about a single axis, as in the case of *epicyclic trains*,[2] in which a frame containing mechanism is made to revolve round a shaft, and the mechanism receives its motion from a wheel or wheels which are either fixed to the shaft or turn about it in various ways. Such motions may be mounted by means of a series of adapters, put on the shaft in sufficient numbers, and either screwed fast to it by their binding-screws, or left free to revolve, as the case may require; and if the shaft itself be required to be fixed, it must be a $\frac{5}{8}$-inch shaft, secured to the head of a bracket by a binding-screw.

(37.) As an example of the way of building up epicyclic trains, fig. 41 shows a model of Ferguson's paradox.[3] A, the bed in section; B, one of its feet; C, a No. 6 bracket, the head of which grasps a short $\frac{5}{8}$-inch shaft in a vertical position; D E, a bar of wood, which can be made to revolve freely and steadily about this shaft by means of an adapter fixed by its nut into a hole bored in the bar, and having its binding-screw loosened or removed. Above this adapter, another is placed on the shaft, and screwed fast to it by its binding-screw. The latter adapter receives the central wheel (F) of the system, and thus fixes it to the shaft. Two common stud-sockets, O, H, are fixed at the proper distances in holes bored in the bar, and thus the train is completed. The central wheel may be of 60 teeth, the intermediate wheel of 50; and for the outer stud-socket (H), three wheels (of 59, 60, 61) must be laid out, either of which can be employed. These are so nearly alike, that if the stud be fixed so as to allow the largest to gear without being pitched too deep, the others will act sufficiently well. The wheel of 60 being first placed on the stud-socket, and a chalk-mark made on its circumference, the frame may be turned, and the chalk-mark will continually point in the same direction. Then the wheels of 59 and of 61 being substituted in turn, they will slowly revolve when the frame is turned, the one in the same direction as the frame, the other in the reverse. This apparatus is very useful to explain the first principles of epicyclic trains.

(38.) It would require a greater number of figures than the plan of this work would admit, to show all the various methods of building up apparatus of

---

[1] A stud-socket will often answer the same purpose as the adapter, and the revolving piece may then be screwed to the stud by its nut. The stud may require to be made of a somewhat different form; but as the stud-socket is bored $\frac{5}{8}$ inch, a short $\frac{5}{8}$-inch shaft may be substituted for the stud.

[2] 'Principles of Mechanism,' p. 361. [3] Ibid. p. 371.

which the system is capable; but the few examples which I shall give below will serve to suggest many others, and will show the general nature and appearance of the machines when set up. With a little practice no difficulty will be found in devising other arrangements to suit any case that may arise. Every combination that proves to be useful must be sketched before it is taken to pieces.[1] Thus the trouble of contriving the same thing over and over every year is saved. The most complex parts may be simplified by having *peculiar* frames or pieces made for the express purpose; but this should only be done after the combination has been tried; for one of the advantages of the system is that it enables us to try various mechanical arrangements, and to reject or improve them as the case may be, without incurring the expense and loss of time consequent upon making frames and pieces on purpose.

(39.) To recapitulate: revolving pieces are, whenever they admit of it, supported by *stud-sockets*, the studs of which are carried by *brackets*, which are supported either on *base-boards, slit tables, rectangles*, or by compound frames built up of *beds* and *rectangles*, combined with *feet, stools*, or *posts*. All these parts are connected by *coach-bolts*. Other revolving pieces are attached to *shafts* by means of *adapters, flanches*, or *pinned rings*, and the shafts are supported either in *carriages*, or by *tube-fittings* or *centre-screws* carried by brackets and by the system of frame-work above described. The shafts are guided endlong by *rings*. The terms in italics, with the addition of *split collars, lever-arms, loops*, and *sole-blocks*, include all the "definite parts" alluded to in Art. 2.

It is perhaps needless to say that drawers with proper compartments should be provided to receive the separate parts of the system, every one of which should

---

[1] It was for this purpose that my ingenious predecessor, Professor Farish, developed the system of Isometrical Perspective now so commonly employed. This method, however, had been previously used, but, I believe, never explained; for example, in volume v. of the 'Machines Approuvées' of the French Academy, 1728, p. 52, there is a large and carefully executed engraving of a machine for milling lead, isometrically projected to scale. The leading lines of the horizontal planes, however, instead of being placed at an angle of 120°, are rectangular, making angles of 45° with the vertical. Thus the distortion of the plan is avoided. (See also tom. vii. p. 126.) I have already stated that the system I have endeavoured to explain has little in common with that of my predecessor, except the idea of employing the same parts in the construction of different combinations of mechanism. In his system, the parts were on a much smaller scale; the toothed-wheels were all of brass, and their pitch five to the inch, which is nearly as small as the Manchester *sixteen-pitch*, the ten-pitch which I employ being about three to the inch. All his revolving pieces were mounted on shafts, and these were made of an *octagon* section, $\frac{3}{4}$ inch diameter. The wheels, &c. were fixed to them by *adapters* (the only feature, in fact, common to our two systems); and to guide this octagon shaft in its revolution, and at the same time to prevent its endlong motion, two rings were fixed to it at the proper points by binding-screws; each ring was $\frac{3}{4}$ inch thick, and consisted of a plain part, 1 inch diameter and $\frac{3}{8}$" wide, which revolved in a hole of these dimensions in the frame-work; and of a flanch, or shoulder,

be carefully put away in its proper receptacle when the machines are taken to pieces. The bolts, washers, &c. should also be placed in drawers, each form having its own cell. The brackets, rectangles, and sole-blocks are best arranged on shelves.

$1\frac{1}{2}$ inch diameter and $\frac{3}{8}''$ thick, which received the binding-screw and also governed the endlong motion. Thus the neck of the shaft was larger than its own diameter. Some of the shafts had pivots turned at one end. There was no provision to prevent the shafts from binding or jamming in their guide-holes, which were made sufficiently loose to obviate this inconvenience. The frame-work was built up of bars of iron, $\frac{3}{4}$ inch square, of which an assortment was provided of various lengths, some straight, some bent into the shape of an L, some in other forms. These were united by *clamps* of a peculiar form, with thumb-screws. The entire plan, into the details of which I cannot further enter, had the merit of great simplicity and ingenuity, but the machines were apt to appear somewhat embarrassed and complicated by the variety of clamps and junctions of the frame-work. It is to be regretted that the ingenious inventor of this mechanism did not draw up a detailed account of his system. The general appearance of his models may be gathered from the sketch of an optical grinding engine appended to his Paper on Isometrical Perspective, in the first volume of the 'Cambridge Philosophical Transactions,' which has also been copied in Gregory's 'Mechanics for Practical Men.'