out by the atmosphere pressing the piston down into the vacuum.

The following is the arrangement by which Mr Buckle accomplished the object which he had in view. P, fig. 121, being the usual piston and cylinder of the steam-engine, L L the usual lever, L R the connecting rod, R O the crank, and R W W W a toothed wheel carried round by the crank, as usual in the steam-engine: there is added *r w w* a smaller wheel of half the number of the teeth of the other, so that during a semi-revolution of the small wheel, the large one performs a quarter of a revolution ; *l I* is a second lever to which there is attached a piston rod L H, carrying a piston from top to bottom of an open cylinder H. When the piston is at the bottom of the cylinder H, the crank R is near the point 1 in the figure. While the crank passes from 1 to 2, it is raising the piston in the pump, and against the pressure of the atmosphere, the steam exerting its greatest force ; but when the crank reaches point 2, the little wheel *w w τ* is at the bottom of its circuit, the piston in the pump is at the top; and now the pressure of the atmosphere carries the piston down into H, turning the little wheel *r w w* along with it, and propelling the large wheel and crank from 2 to 3, through that part of the stroke where there is a cessation of the action of the steam : then again from 3 to 4 the excess of the power of the steam is employed in raising the pump piston; while from 4 to 1 the piston of the pump, carried down by atmospheric pressure, brings round the mechanism once more to the point 1.

So perfect was the action of this mechanism that the flywheel had been wholly removed, and the engine and the whole millwork were moving in the most smooth and effective manner. It was found that the change enabled them to give all the grinding stones a greater velo city than formerly, so that the quantity ground was greater, in the proportion of 56 to 52, and the quantity of the finest or first flour, from the same wheat was like wise much increased ; so that, both by quantity and qua city, the owner of that mill was now able to “ command the market.” The same motion has subsequently been applied to cotton-mills with perfect success ; the quality and the quantity of yarn produced being much improved.

From the circumstance already noticed, that at one point the steam possesses no power of giving revolution to the crank, it has been imagined that some considerable Ioss of the power of the

steam takes place during

the transmission of its

moving force through the

crank. This is a grave

error, and it has produced

other errors, which we

shall consider in our chapter on rotatory steam-engines.

Figs. 122 to 125 re present the crank in diffe rent positions. In figs.

122, 125 the connecting rod and crank are in the same straight line, techni­cally called the position “ on the centre,” or passing the line of centres, in which the action of the crank neither tends to produce motion in the one direction nor the other. Again, at M and N, figs. 123, 124, where the crank is represented as acted upon at right angles by the connecting-rod, it is plain that the whole force transferred through the rod is acting to produce the effective motion of the crank ; while in the intermediate positions there are two effects produced, one acting on the centre of the crank, and another acting to

give it revolution. For the purpose of examining the proportion of these forces to each other, we may use the two following diagrams :

Fig. 126 represents the circle of the crank, the ar **γows** showing the direction in which the crank-rod would require to act, in order that all its force should be un­divided, and produce alone the single effect of causing revolution. Fig. 127 indicates the deviation which the actual motion of the crank exhibits from this hypothetical condition. The arrow *a* indicates the direction of the action of the connecting-rod, which at divisions 10 and 20 is acting only towards the centre of the circle with no effect in producing revolution. At divisions 5 and 15, the whole effect takes place in producing revolution only. Through the first half of the circle the pressure of the rod acts wholly downwards, and through the latter half of the stroke wholly upwards. The circumference of the circle being divided into 20 equal parts, the analysis of the force is given in the figure at several of these points. At the second division, *a* re presents the direction of action of the crank-rod, *b* is parallel to the direction of the circumference (or tangent) of the circle at that point, while the line *c* is directed to the centre ; *a* indicating the direction of the whole force of the connecting-rod, *b* representing the effect produced in the direction of the tangent to turn it round, and *c* the effect of the force of the connecting-rod acting to produce pressure on the centre of the crank ; but as the centre of the crank is fixed and prevented from moving, none of the moving power of the crank is given out in producing motion towards the centre, but only in producing motion in the circumference. At the fourth division of the circumference, it may be observed, that the effect of the connecting-rod is differently distributed. The whole force *a* is now more nearly in the direction of *b,* and *c* is comparatively small ; showing that as we approach the end of the first quarter revolution, the force of the connecting-rod is producing much less pressure in the centre of the crank, and pressing in a higher proportion in the direction of the revolving effect, until at last the connecting-rod being at right angles to the crank, its whole pressure acting to turn round the crank, none of it is directed towards the centre. After passing the quadranted point 5, the crank-rod still presses downwards, as shown by the arrow *a* at point 7 ; but, at its two effective pressures, one represented by *b* still acts in turning round the crank, while another represented by *c,* instead of act­ing towards the centre, as in the upper quadrant, now produces a pressure which would draw the crank away from the centre ; but as the crank is fixed, none of the motive power is employed in producing any motion of the crank away from its centre. Similar alternating effects are produced through the other quadrants ; so that, while the pressure of the steam, acting through the connecting-rod upon the extremity of the crank, is divid ed into two effects, one of these is prevented from expending the moving force of the engine by the fixed ness of the crank centre, and the whole motive power is given out only at the circumference of the crank circle in turning it round, but in a proportion of pressure