The Undulator*

A Modified Reciprocator for Ornamental Lathes

By A. S. Rogers

"ATKINSON'S RECIPROCATOR," as an adjunct to the spiral apparatus of the ornamental lathe, is well known to ornamental turners. By this appliance simple waved lines are produced lengthwise upon cylindrical and taper forms, and radially upon surfaces, by combining

Fig. 1.—Ratchet Wheel.

a rocking motion imparted to the mandrel by an eccentric clamped to one of the gear-wheels with the traverse of the tool or a revolving drill in the slide-rest.

The chief difference between the original apparatus and that now to be described lies in the substitution

Fig. 2.—Radial Lever.

of "cams" for the eccentric. Cams may be either counteracting or single-acting. The counteracting cam, as its name implies, gives a positive motion; while the single-acting requires the use of a spring or weight to obtain the return action. The cam has this great advantage over the eccentric, that as its shape can be

Fig. 3.—Axle

varied to an almost unlimited extent, so the motion imparted by it will be similarly varied. With cams, undulations can be produced on the work such as zigzag or dog-tooth patterns, step patterns, and complex patterns composed of curves, angles, and straight lines. By the adoption of the single-acting cam, patterns may be made to proceed spirally round cylindrical and taper work. Spiral effects were obtained by the older apparatus; but what is referred to here is the spiral advance round the cylinder of the single waved or undulated line. Another variation can be produced which is analogous to the effect of the stop-screw upon the Rose cutting-frame, which limits the action of the rosette by preventing the roller from descending to its full depth.

* Reproduced from the *English Mechanic*.

Fig. 4.—Washer.

Enough has been said to show that a considerable addition may be made to the powers of the original appliance; but before commencing to give details of construction, it will be well to premise that correct measurements can scarcely be given to suit all lathes. The parts to be described may be adapted to any lathe which has facility for fixing a gear-wheel at the rear end of, and outside, the headstock. It is presumed that there will be a feather or studs let into the mandrel at this point, upon which the screw-guides of the traversing mandrel or the pinion-wheel fit.

Fig. 5.—Sleeve

A gunmetal wheel is bored out to fit upon the mandrel and turned up to 1 11/16 inches diameter and 5/8 inch in thickness, and the keyway is cut. One side of the wheel is then reduced to form a boss 1 1/4 inches diameter and 5/16 inch long. This leaves the edge of the wheel 5/16 inch thick. This edge is cut into ratchet-teeth, forty-eight in number, and the direction of the teeth the same as in Fig. 1. This wheel and the boss of the radial lever, which is hollowed out to receive it, together form the dividing-chuck. The radial-lever has a long slot instead of the numbered holes of the older apparatus (see Fig. 2). Its dimensions are 6 3/4 inches long over all, by 5/16 inch thick, by 1 1/4 inches wide; boss 1 15/16 inches outside diameter, thickness of boss and lever together 5/8 inch. The slot is 3/8 inch wide. The ratchet-wheel is wholly contained within the thickness of the lever and boss, and should fit freely, but without shake. The axle which rides in the slot is shown in Fig. 3. It is 3/8 inch diameter, and 3/16 inch thick. Both ends are tapped and fitted with 5/16 inch nuts, and the end of the axle is drilled up and carries a steel pin, upon which is hung the spiral spring which provides the return motion required by the single-acting cam mentioned above.

A short continuation of the radial lever carries the long-tailed ratchet shown in Fig. 2. The milled-headed

Fig. 6.—Cam-Wheel Axle

screw, which is tapped through the tail of the ratchet, locks the ratchet-wheel and radial lever together after using the device as a dividing chuck. When a movement of the ratchet-wheel is required the screw is slackened, and the click of the ratchet is easily counted as the lathe pulley is slowly moved round. The wall of the recess in the boss is cut away at one point to allow the point of the ratchet to reach the teeth.

The ratchet-wheel is placed upon the mandrel first, with the boss outside; the radial lever is next put on over the wheel, the large washer with the raised projection, as shown in Fig. 4, is put in place, and then all are screwed up with the nut or screw at the end of the mandrel. The projection on the washer bears upon the boss of the ratchet-wheel, so as to fix it, while still leaving the lever free to move when the milled-headed screw is loosened.

In the original apparatus the hub of the eccentric and a gear-wheel were clamped together upon a re-

volving axle. In the present case the cam is screwed to the boss of a gear-wheel with two 3/16 inch counter-sunk head screws, and the axle on which they work is a fixed, and not a revolving, one. A special wheel should be made, of 120 teeth; the boss should be 1 1/2 inches across the face, not larger; the bore is to be 5/8 inch, and the thickness the same as the other wheels

Fig. 8.—Roller and axle.

of the set. With this sized wheel and a suitable combination of the gear-wheels, the wave length may be reduced to 2/10 and increased to 3 inches or more. To fit the 5/8-inch hole in this wheel a steel sleeve will now have to be made, 1/4 inch longer than the thickness of the wheel, and with a thin collar at one end

Fig. 9.—Stop-plate.

3/16 inch thick and 15/16 inch diameter (see Fig. 5). The hole through the sleeve is to be 1/2 inch, as this is the size of the axle on which it will run. In use the sleeve centralizes the cam upon the wheel, and allows both to be screwed together without tightening the running fit upon the axle. It also prevents the wearing of the holes in the wheel and cam.

Fig. 10.—Stud.

Fig. 6 shows the cam-wheel axle, the sizes being collar 1/4 inch thick and 1 1/2 inches diameter; fitting for banjo plate 1 inch diameter filed down to 3/4 inch to fit slot; thread 1/19 inch pitch = 3/8 inch gas-barrel thread, length 5/8 inch. The axle is turned up 1/2 inch diameter to fit the sleeve, the end is reduced and tapped 5/16 inch, and a hole is drilled up the end for a steel pin to carry the lower end of the spiral reaction spring.

The next part to be taken in hand is the connecting-arm, which is shown in Fig. 7. This is a flat arm 9 1/4 inches long, 1 1/2 inches in width at the wider end, and 1 inch at the narrower. The total length of the arm

Fig. 11.—Sliding boss.

may be shortened if the size of the banjo-plate requires it. The slot is 3 inches long by 5/8 inch wide, and the boss is 7/8 inch diameter by 5/8 inch through the hole, which is bored out 3/8 inch to fit upon the axle (Fig. 3). At distance 3/8 inch from the inner end of the slot a 1/4-inch tapping hole is drilled and tapped. This is to carry the axle for the roller which is operated upon by the cam. Fig. 8 shows section of roller, and its axle, locknut, and retaining screw. The roller is 3/4 inch

Fig. 7.—Connecting Arm.

diameter and $\frac{1}{2}$ inch long, $\frac{5}{16}$ inch in the hole, recessed at one end for the head of the retaining-screw, and is casehardened. The locknut serves a double purpose. It is only $\frac{3}{8}$ inch diameter, and being made cylindrical, it has a saw-cut across the end, to allow of it being screwed up with a forked screwdriver. The

Fig. 12.—Cam.

cylindrical exterior to the nut serves as one of the two $\frac{3}{8}$ -inch studs, upon which a stop-plate (Fig. 9) rides by means of its slot. The plate is $3\frac{1}{2}$ inches long by $\frac{1}{8}$ inch wide, and $\frac{3}{16}$ inch thick, and has a slot $\frac{3}{8}$ inch wide and $2\frac{1}{2}$ inches long. The second stud (Fig. 10) is tapped into the connecting arm at a distance of $\frac{13}{16}$ inch away from the center of the roller axle. This stud is also $\frac{3}{8}$ inch diameter where the slot of the stop-plate rides upon it. One end of the stud screws into the arm and has a locknut on the back, and the other end carries a washer and nut to fix the stop-plate in any position it may assume under

Fig. 13.—Jig.

the guidance of the two studs. The hollowed end of the stop-plate strikes against a loose sliding boss which rides upon the cam-wheel axle and in the slot of the connecting arm, and so prevents the roller from reaching the bottom of the cam. This is the device referred to when mention was made of the rose cutting-frame.

Fig. 11 shows the sliding boss, which is made in two parts. Cast iron is a better material for the main part than gunmetal or brass. Get a circular casting $1\frac{7}{16}$ inches diameter by $\frac{3}{4}$ inch thick, bore out the $\frac{1}{2}$ -inch hole to fit the cam-wheel axle, and turn up on a mandrel to $1\frac{5}{16}$ inches by $\frac{5}{8}$ inch. Then file or plane part of the sides away at one end until two

Fig. 14

Fig. 15
Adjustable coupling.

Fig. 16.

shoulders are formed, and the part so reduced will enter and fill the slot in the connecting arm, and slide smoothly from end to end. The hole through the boss will serve as a guide for centralizing the fitting, and a line scored round the boss while in the lathe will give the depth of the shoulders. A gunmetal washer $1\frac{5}{16}$ inch diameter, with a $\frac{1}{2}$ -inch hole and $\frac{5}{32}$ inch or $\frac{3}{16}$ inch thick, should now be screwed to the cast-iron boss by two $\frac{3}{16}$ -inch countersunk-head screws, one screw being tapped into each end of the boss. It is against the edge of this washer that the stop-plate strikes.

The movement of the sliding boss in the slot of the connecting arm should be greater than $1\frac{1}{2}$ inches, and if the reduced part of the iron casting be rounded

Fig. 17.—Brake.

at the ends this amount of movement will be easily attained. The reason for this requirement lies in the dimensions of the cams, which have a throw—from lowest to highest point—of $1\frac{1}{2}$ inches. The central inoperative part of the cam is also $1\frac{1}{2}$ inches, and for this reason the boss of the 120-tooth cam-wheel should not exceed this diameter; as otherwise the roller, when at the bottom of the cam, might strike and interfere with the proper motion.

Fig. 18.—Undulator patterns.

At this stage a sketch of one of the cams will be useful. (See Fig. 12.) The cam here shown produces a pattern which may be described as a zigzag with the apices flattened. A simple jig (Fig. 13) for drilling the two screw-holes should be made from a piece of $1\frac{1}{4}$ -inch by $\frac{1}{8}$ -inch iron or steel plate, $2\frac{1}{2}$ inches long. Bore out a clean hole $\frac{5}{8}$ inch diameter to fit the steel sleeve, scribe a line $\frac{1}{8}$ inch away from, and parallel to, the diametrical line, and having put the sleeve through the hole, drill two $\frac{3}{16}$ -inch thoroughfare holes upon the line and just avoiding the collar of the sleeve. To use the jig, bore a $\frac{5}{8}$ -inch hole through the material for the cam, lay the jig upon it, and put

to one another, or else the wave will be distorted. This adjustment is attained by moving the cam-wheel axle in the slot of the banjo-plate until the position is found. The banjo-plate is then lowered until the cam-wheel gears with the wheel upon the leading-screw extension shaft, or one of the compounding wheels, as the case

Fig. 19.—Undulator patterns.

may be. Bear in mind any movement of the axle in the slot of the radial lever requires a readjustment to the right-angle central position.

An adjustable coupling has been introduced between the end of the slide-rest screw and the small steel shaft connecting it with the first gear-wheel, as a more certain and convenient means of shifting the wave lengthwise upon the work than the old method of lifting the wheels out of gear while the leading-screw is moved. This coupling is on the ratchet principle, and the wheel is of the same size, but only half the number of teeth of the one inclosed in the boss of the radial lever (Fig. 2). The ratchet is precisely similar. Figs. 14, 15, and 16 show details of the construction of the adjustable coupling.

The dimensions in Fig. 15 are: Ratchet-wheel $1\frac{11}{16}$ inches diameter by $\frac{5}{16}$ inch thick, 24 teeth; boss, $1\frac{1}{2}$ inches diameter by $\frac{3}{4}$ inch long. This boss should be bored out to fit upon the socket fixed on the left-hand end of leading screw. Fig. 14 represents the other half of the coupling, and consists of a boss 1 inch diameter by $\frac{3}{4}$ inch long (boss is shown $1\frac{1}{2}$ inches diameter in sketch); a flange $2\frac{1}{2}$ inches diameter by $\frac{5}{16}$ inch thick, and which is eccentric to the boss; and a receptacle to carry the ratchet-wheel. This re-

Fig. 20.—Undulator patterns.

ceptacle is concentric with the boss, and has inside measurements of $1\frac{11}{16}$ inches diameter by $\frac{5}{16}$ inch deep, and outside $1\frac{15}{16}$ inches by $\frac{3}{8}$ inch. The eccentricity of the flange is such that its edge just coincides with the outside of the receptacle at one point in its outline. The boss on this side of the coupling is bored out to fit the end of the light steel shaft connecting with the gear-wheels; but this hole should not be bored until the central internal screw shown in section in Fig. 16 has been fitted.

The lengthwise shifting of the wave to elaborate the pattern usually requires a considerable movement of the winch-handle of the leading-screw. Supposing a wave-length of 5 tenths is to be shifted one sixth of its length for the second series of cuts, and again one sixth for a third series, and so on. To do this, slacken the milled-headed screw of the ratchet, hold the eccentric flange, turn the handle of the leading-screw (assumed to be $\frac{1}{10}$ inch pitch), and count twenty clicks of the ratchet, i. e.,

$$\frac{5 \times 24}{6} = 20$$

Then tighten the ratchet-screw again. If whole turns of the leading-screw are required, loosen the ratchet-

Fig. 21.—Old reciprocator wave.

Fig. 22.—Old reciprocator wave doubled.

the sleeve through both holes, collar uppermost. Drill one hole first with a twist-drill, insert a well-fitting peg, and then drill the other hole. The jig will be used in the same way for drilling the holes in the boss of the 120-tooth cam-wheel, except that the holes will be marked with a full-sized drill and finished with tapping size. The jig should always be used with the same side upward, and the holes in the cams should be countersunk on the same side on which they were drilled, and then every cam will go in its place without fail.

In designing this apparatus, regard has been had to easing the motions of the cams as much as possible; the wear of the cam is thereby reduced, and a very satisfactory cam can now be made out of $\frac{1}{4}$ -inch white holly, a material easily obtained from fretwood dealers. Metal cams are necessarily superior to wood, and rolled brass $\frac{1}{4}$ inch thick and 3 inches to $3\frac{1}{2}$ inches wide, is a handy form of material for the purpose.

Referring again to Fig. 12, a line drawn on the cam will be noticed, and it denotes the two points midway between the bottom and the top of the rise, or the middle point of the motion of the connecting arm. When the roller is upon these midway points, the connecting arm and the radial lever must stand at right-angles

screw, observe the reading of the micrometer upon the leading-screw, hold the eccentric flange, give the requisite number of turns, and fix the ratchet-screw again. Further, if the tail of the ratchet be depressed after the ratchet-screw has been slacked, movements may be made in either direction at will, counting by divisions figured on the side of the ratchet-wheel.

The spiral advance of the single waved line round the cylinder, which has been previously mentioned, involves the use of a brake or friction-pad to steady and control the movement of the lathe mandrel. This brake is carried in the socket of the dividing index, and is shown in Fig. 17. The pad or brake bears upon the flat surface of the division plate, which is not hurt in the slightest by its use. A taper fitting, reduced at the smaller end to carry a washer and a small wing-nut, is made to the socket. The larger end, nearest the division plate, is turned down, and a piece of strong clock-spring, about $\frac{3}{4}$ inch wide and $3\frac{1}{4}$ inches long, is riveted on with a washer under the head of the rivet to support the spring. About $\frac{1}{4}$ inch of the upper end of the spring is bent over at right-angles toward the division plate, this end being softened before bending. The spring and taper fitting are then put in place and screwed up with the wing-nut. A block of wood about $1\frac{1}{4}$ inches square is then made, rather thicker than will fill the space between the spring and the division plate, and is fixed to the spring close under the bent end. Two short wood screws $\frac{3}{8}$ inch long will suffice to hold it. The block and spring are then tried in place, together with a piece of new "boot-upper" leather the size of the block. It will probably be found that the wood block requires tapering down in thickness to make it fit the division-plate. The leather is then fixed to the wooden block with "Prout's elastic glue," an invaluable compound, and four wooden boot-pegs are driven through the leather and into the wooden block, to make all secure. The leather should then be greased.

When the brake is in place the lathe-pulley should move stiffly if pulled round with one finger and thumb. All that is required is that the revolving drill shall not have power to move the work while the mandrel is controlled by the brake alone. There are really three points to consider when the advancing spiral wave is being made: First, the resistance of the brake; second, the power of the spring under the ratchet tail, and this should be only strong enough to make the point of the ratchet sure of bottoming in the tooth of the wheel; and, third, the power of the spiral spring which provides the return motion, and this may be fairly strong. A suitable spring is made of 17 B.W.G. hard-drawn steel wire, barrel $\frac{1}{2}$ inch, length over all, about $5\frac{3}{4}$ inches. This spring requires a pull of 6 pounds to extend it to $6\frac{1}{2}$ inches.

The spiral produced is necessarily of an interrupted character, the rising half of the cam causing the advance, while during the falling half the mandrel is at rest; for the ratchet being left quite free to work uncontrolled by the milled-headed screw, and the mandrel being held by the brake, the radial lever returns to its first position without moving the work, and then rises again and causes a further advance. The effect upon the work is that one half the wave is followed by a straight line, which is, in turn, followed by another half-wave, and so on.

With reference to the sketches accompanying this paper, some of the figures are lettered *F*, *R*, and *L*. These letters denote the position in which the parts stand when seen from the front of the lathe. *F* = front, *R* = right side, *L* = left side.

A few specimens drawn by the apparatus are given, just to show the kind of patterns obtainable, the selection being made to show how completely they differ from the patterns produced by the older apparatus. Figs. 18, 19, and 20, Undulator; Fig. 21, Old Reciprocator Wave; Fig. 22, Ditto doubled.

Mathematics for Recreation

By F. B. Selkin

[The reader, after perusing the arguments presented below, may perhaps at first find his faith in the logical security of mathematical reasoning shaken. It will be a good exercise for his critical judgment to seek to discover the fallacy involved in the arguments given.—ED.]

1. Theorem. Any number is equal to any other number, or, all numbers are equal to one another.

Let *a* and *b* be any two numbers, and let *c* be their difference.

Then $a-b=c$

Multiplying both members by $a-b$,

$$a^2-2ab+b^2=ca-cb,$$

whence $a(a-b-c)=b(a-b-c).$

Therefore $a=b.$

In other words, any two numbers are always equal.

* Reproduced from the Teachers' College Record.

2. Theorem. Any two unequal numbers are always equal.

Let *a* and *b* be two unequal numbers, and let *c* be their arithmetical mean.

Then $a+b=2c.$

Therefore $(a+b)(a-b)=2c(a-b).$

Therefore $a^2-2ac+b^2=2bc,$

and $a^2-2ac+c^2=b^2-2bc+c^2.$

or $(a-c)^2=(b-c)^2.$

Hence $a-c=b-c$

and $a=b.$

But *a* and *b* were taken as unequal. Hence any two unequal numbers are always equal.

SPECIAL CASES.

1. To show that 1 equals 2.

Let $a=b.$

Then $ab=a^2.$

Hence $ab-b^2=a^2-b^2.$

and $b(a-b)=(a+b)(a-b).$

Therefore $b=a+b,$

or $b=2b,$

and $1=2.$

2. To show that 2 equals 3, 5 equals 7, and 9 equals 5.

By a somewhat similar reasoning we can show that 2 equals 3.

For $2^2-2\times\frac{5}{2}\times 2=3^2-2\times 3\times\frac{5}{2}$

Completing the squares by adding $(\frac{5}{2})^2$, or $\frac{25}{4}$, to each member we have:

$$(2-\frac{5}{2})^2=(3-\frac{5}{2})^2,$$

whence $2-\frac{5}{2}=3-\frac{5}{2},$

and $2=3.$

To prove that 5 equals 7:

Let $a=\frac{3}{2}b,$

Therefore, $4a=6b,$

or $14a-10a=21b-15b,$

and $15b-10a=21b-14a,$

or $5(3b-2a)=7(3b-2a)$

Hence $5=7.$

We can also show that 9 equals 5.

For, $9+5=2\times 7$

Multiplying both members by $9-5$, we have:

$$9^2-5^2=2\times 7\times 9-2\times 7\times 5.$$

Therefore, $9^2-2\times 9\times 7=5^2-2\times 5\times 7.$

Adding 7^2 to both members,

$$9^2-2\times 9\times 7+7^2=5^2-2\times 5\times 7+7^2,$$

or, by taking the square root, $9-7=5-7.$

Hence $9=5.$

3. To show that -1 equals $+1$.

Furthermore, $+1$ equals $-1.$

For, $\sqrt{a}\times\sqrt{b}=\sqrt{ab},$

whence $\sqrt{-1}\times\sqrt{-1}=\sqrt{(-1)(-1)},$

or $(\sqrt{-1})^2=\sqrt{1},$

whence $-1=1.$

Distribution of Sugar in the Beet Root

THE distribution of sugar and non-sugar substances in the beet root has considerable importance, both from the point of view of vegetable physiology and of sampling for commercial purposes. Some work has already been done in this direction, but in the opinion of Messrs. Floderer and Herke, quoted in *Knowledge*, its accuracy is

A diagram illustrating the distribution of sugar in the beet root.

open to question, owing to the defective methods of dividing the roots for the analysis. Accordingly, they have made a fresh investigation, using for the purpose fifty roots of uniform size, which they divided into ten transverse sections and sub-divided into concentric rings in the manner shown in the diagram. The respective corresponding pieces from each of the roots were mixed

together so that in all nineteen separate lots were obtained for the analysis.

The results showed that the sugar (sucrose) was present in the greatest proportion in the innermost portion of the root, those sections between the middle axis and the part where the root began to taper being the richest. Thus the most sugar was found in the following sections: 14, 15, 19, 13, 12, 18, 17 and 16; and then in decreasing quantities in 11, 6, 8, 5, 4, 3, 7, 9, 2, 10 and 1. Whence it appears that the body of the root is richest in sugar and the crown the poorest.

With regard to the other constituents it was found that the total solid substances varied but little in any part of the root, with the result that a rise in the proportion of sugar was accompanied by a decrease in the amount of non-sugar substances. In fresh beet roots the proportion of soluble nitrogenous bodies was lower in the interior parts, while the mineral constituents (ash) varied inversely with the amount of sugar. A decrease in the amounts of potash and magnesia was observed on proceeding from 1 down to 15, where the sugar was present in greatest proportion, after which both substances increased with the fall in the sugar. It was not possible, however, to establish any relationship between the amounts of sugar and phosphoric acid.

Italy to Adopt Gasoline Haulage.—As one result of the experience of the Italian War Office in the Tripoline campaign in Africa, it has been decided to adopt on a large scale motor haulage, in lieu of horses, for heavy artillery. Foreign, as well as Italian, manufacturers are invited to tender for contracts which cover from 70 to 80 suitable vehicles.

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