A Reader's Model In Meccano

N.S.U. - Wankel Engine

By T. C. Nuttall

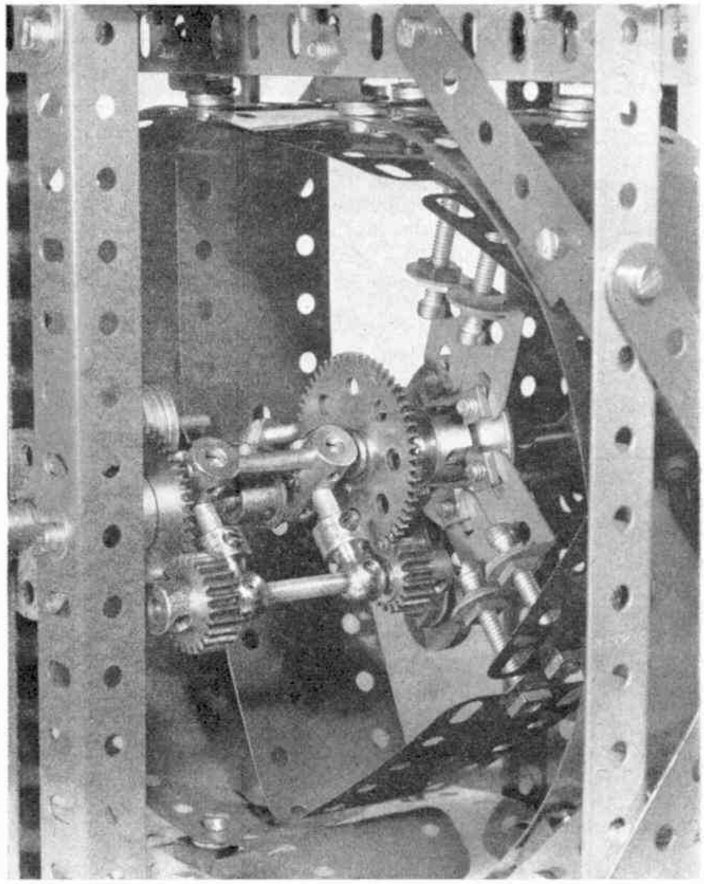


Fig. 1. The gear arrangement of the Meccano model N.S.U. - Wankel Engine described in the accompanying article.

ENCOURAGING progress reports have recently provided interesting news of the N.S.U.-Wankel Engine, which is being developed by the N.S.U. Company in Germany and the Curtiss Wright Corporation in America. This engine works on the normal four-stroke principle, but it uses *only two moving parts* in place of the multiplicity of cranks, connecting rods, pistons and valve gear of the conventional four-stroke engine.

One of the moving parts is a sturdy crank, of short throw, formed on the output shaft of the engine. The crank carries the other moving part, which is a rotor whose section is in the form of an equilateral triangle with slightly convex sides. The dimension of the rotor from its centre to any apex is some six to eight times the throw of the crank. Mounted on the rotor is an internally toothed gear ring, which rolls round a gear wheel fixed to the engine casing. By this means the rotor is made to rotate in the same direction as the crank, but at exactly one third of the speed. Thus, as the crank rotates, each point of the triangle in turn traces out the same path in space. The shape of this path (a form of trochoid) shows a maximum diameter at the two points where the crank throw is added on to the rotor dimension, and a minimum diameter, or waist, at the two points where the crank throw is subtracted from the rotor dimension.

Three Compartments

The engine casing is made with an internal surface whose shape matches the path traced out by the corner edges of the rotor. The rotor edges are provided with gas-tight seals to the casing (similar in principle to piston rings), so that the rotor divides the available space into three separate gas-tight compartments whose volumes change as the rotor turns. In making one complete circuit of the periphery each compartment expands and contracts twice. This is exactly what is required to carry out the standard four-stroke Otto cycle. Inlet and exhaust ports are provided through the casing but no additional valve gear is required since the ports can be so positioned that they are uncovered and covered at the right times by the movement of the rotor. On the opposite side of the casing a recessed sparking plug ignites the mixture when at maximum compression (one spark per revolution of the crank).

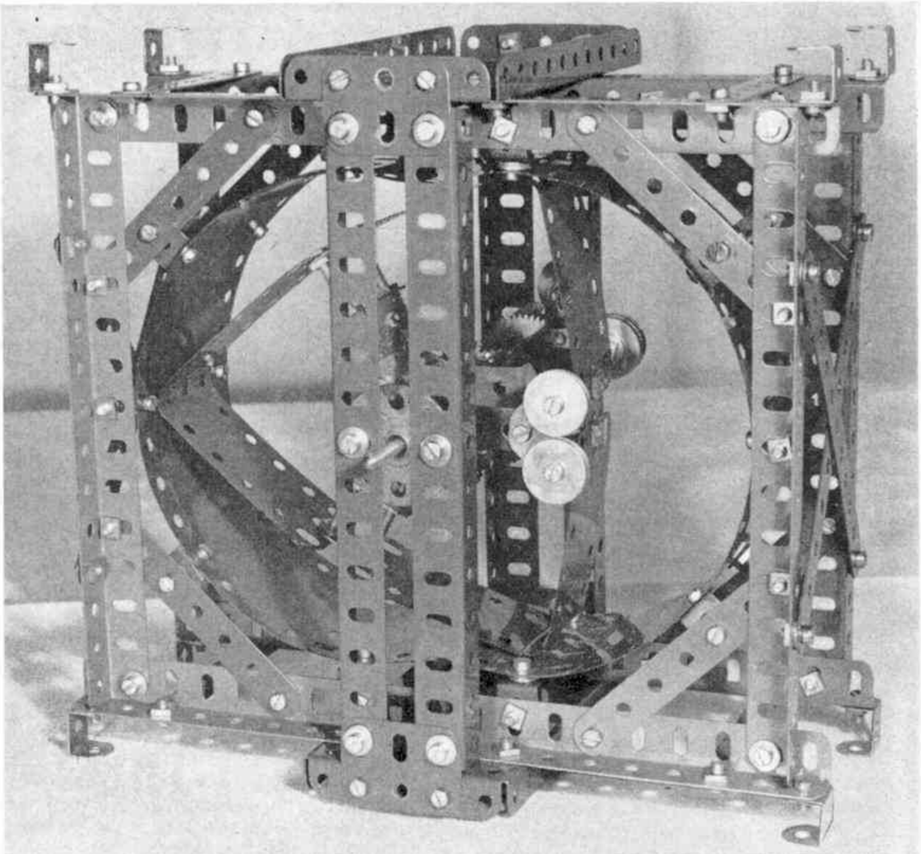
Since the moving parts have only uniform circular motions their masses can be completely balanced and the engine is quite free from mechanical vibration. It can therefore be run quite safely at much higher speeds than a similar capacity engine of conventional design whose reciprocating parts cannot be completely balanced. Higher speed implies that for a required power output the new engine is smaller, lighter and in the long run probably cheaper to produce than the conventional engine. Descriptions of the engine, and of the problems which have had to be overcome, appeared in *The Motor Cycle* of February 18 and 25 and *The Autocar* of February 19 and 26, 1960.

The manner in which the moving rotor changes the shapes and volumes of the compartments is not at all easy to visualise without the aid of a model, and so the Meccano model shown in the accompanying photographs was constructed.

The crank is built up of Rods connected by being passed through the transverse holes of Couplings. Extra strength is provided by using two Couplings for each web of the crank. This construction fixed one important dimension, the crank throw, at ½". To duplicate the gear arrangement of the real engine in the model with a crank throw of ½" would require a gear ring and a gear wheel of pitch circle diameters of 3" and 2". In terms of Meccano pitch gears this would imply a gear ring with 114 internal teeth rolling round a gear wheel with 76 teeth and since these are not available, an alternative method was used. The solution adopted is shown in Fig. 1. A 50-tooth Gear Wheel is fixed by a Socket Coupling to a Bush Wheel forming one of the main bearings, the Bush Wheel being bolted to the framework. The centre of the rotor comprises a 6-hole Bush Wheel fixed by a Socket Coupling to a 57-tooth Gear Wheel, the combination being free to turn on the crank. The two Gear Wheels are linked by a layshaft carrying a 25-tooth Pinion, engaging with the stationary 50-tooth Gear, and a 19-tooth Pinion engaging with the 57-tooth Gear. The layshaft is journalled in two Handrail Couplings mounted on the ends of 1" Rods fixed through the centre transverse holes of the Couplings forming one web of the crank.

Readers who enjoy gearing problems will find it an interesting exercise to prove that this arrangement does, in fact, produce the required result, which is three revolutions of the crank to one revolution of the rotor.

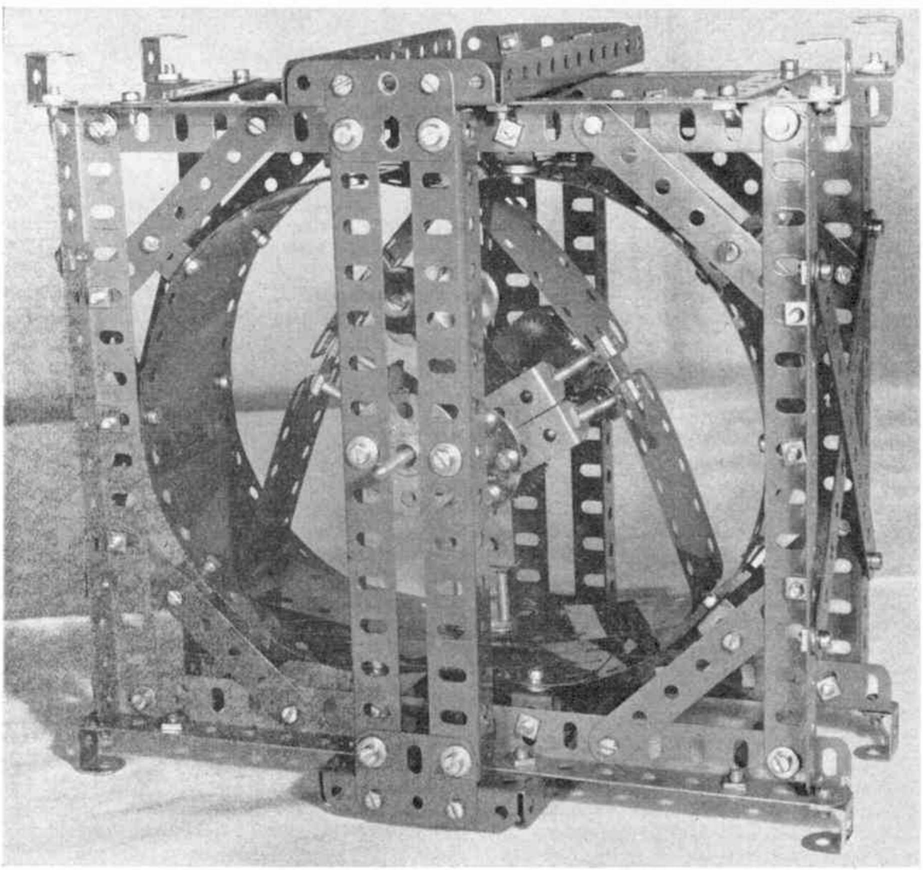
Fig. 2.
The Meccano model N.S.U.-Wankel Engine. In this view the right compartment is seen at its maximum volume.



Choice of Ratio

In a true scale model the ½″ crank throw would serve to determine all the other dimensions of the model. It is reported that the N.S.U. engines so far built have all had an axial length four times the crank throw. It is interesting to note that the resulting 2″ scale length is mid-way between the widths of the Flexible Plates (1½″ and 2½″) used to form the rotor and casing although, of course, the model is primarily intended to represent the section of an engine rather than the complete engine. Attention to scale is desirable in choosing the rotor dimension (centre to apex) as the ratio of this dimension to the crank throw determines the shape of the trochoidal curve. Too small a ratio (say less than 6) produces a pronounced waist with sharp curves. In the real engine this gives trouble with the oscillation of the angle of pressure on the apex seals and the reversal of the centrifugal force on the seals as they negotiate the reversed curvature at the waist (the reversed centrifugal force increases the amount of spring loading necessary to hold the sealing blades in contact with the casing). With a large ratio (9 or more) the waist disappears, but a large ratio increases the overall size of the engine out of proportion to the useful swept volume. For the purposes of the model any ratio between 6 and 8 would be satisfactory, and the exact choice can be made to suit the method of construction.

Fig. 3.
Compare this view with Fig. 2. Here the bottom compartment of the engine is at its minimum volume.



The Flexible Plates forming the casing require several points of support to fix and maintain the required shape, and the most symmetrical mounting arrangement will be obtained if the perimeter is a multiple of 4 holes. It is found that 44 holes (22″) gives a suitable size, the maximum and minimum diameters of the trochoid being 7½″ and 5½″, corresponding to a rotor/crank ratio of 6½.

The required 22″ length of Flexible Plate is made up of four 5½″ lengths and two 3½″ lengths. This provides generous overlaps, and more important, permits a convenient allocation of the Plates to different parts of the curve. The 5½″ lengths are used for the gently curved, almost circular, lobes of the trochoid, while the 3½″ lengths cover the trickier re-entrant curves at the waist. The Flexible Plates are fixed to the supporting framework by ten Angle Brackets along each edge. A few spacing Washers and the use of the slots in the Angle Brackets and Girders provide the necessary adjustments which, with a little careful bending of the Plates, allow the required shape to be set up. There is no

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Stamp Gossip—(*Continued from page 69*)

than ten years ago. It works out at 196 per capita, to use an expression beloved by our American neighbours. We made 4,189,000,000 telephone calls during the same period. This number included 840,000 to ships, and we asked the G.P.O. for Indian Test Match scores 1,750,000 times. How many calls will we put in this summer, when we are beating the Australians? As for stamps, I am told the printers issue 30,000,000 a day to keep up with our demands, and in doing £5,850,000,000 worth of business with us the P.O. took a neat little £20,900,000 profit for itself, which I think is very naughty, seeing that we are dealing with a government monopoly which, in my view, should not make a profit.

THE TIP OF THE MONTH

Now that special efforts are being made officially to push the sales of British Commonwealth stamps of the present reign there is already an increasing demand. This means that obsolete "QE" stamps should be picked up with as little delay as our pockets will allow, as some of these stamps which today only cost coppers will make as many shillings by and by. Verb sap!

N.S.U.-Wankel Engine
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difficulty in finding the right shape, for as soon as the rotor is mounted up and turned each apex traces out the required curve and shows directly where any adjustment is required.

The photographs show how the rotor shape is built up of $5\frac{1}{2}'' \times 1\frac{1}{2}''$ Flexible Plates and Fishplates, and mounted with $1\frac{1}{8}''$ Bolts and nuts from $1\frac{1}{2}'' \times \frac{1}{2}''$ Angle Brackets fixed to the 6-hole Bush Wheel. The slots in the Fishplates and the ends of the Flexible Plates allow the perimeter to be extended to the required value and the nuts on the $1\frac{1}{8}''$ Bolts allow the convexity of the flanks to be adjusted.

Theoretically, to fit the trochoid, the dimension from the centre of the rotor to each apex would be $3\frac{1}{4}''$ and to the centre of each flank a maximum of $2\frac{1}{4}''$. It should be clear, however, that in a Meccano model there can be no question of achieving a gastight fit! The object in the model is to show each apex travelling close to the trochoid but without actual contact. A working clearance of approximately $\frac{1}{16}''$ can be achieved, the limit being finally determined by small wobbles of the rotor permitted by backlash in the gearing.

The object in using convex rather than straight rotor flanks is to reduce the clearance volume at full compression, and so to achieve a satisfactory compression ratio, but since the compressed gas must be able to pass from one side to the other, a gastight fit of the rotor flank to the trochoid waist would not be suitable. In the real engine, channels are cut in the rotor flanks to permit passage of the gas. The rush of the compressed gas through the channel creates turbulent conditions which promote efficient combustion without "pinking", even when using low octane rated fuels, which would certainly "pink" in a conventional engine of similar compression ratio.

The stacks of $\frac{3}{4}''$ Washers, prominent in Fig. 2, are used as balance weights. If the model had been symmetrical the balancing would have been shared equally between balance weights on each end of the main shaft, but because of the unsymmetrical gear arrangement the balance weight on the gearing end of the model has to be increased in weight (2×9 washers instead of 2×5) and shifted in angular position so that it can take care of the balancing of the layshaft in addition to its half share in the balancing of the rotor. Since the remarkable performance of the real engine is largely dependent on its perfect mechanical balance, it is interesting to note that this feature is clearly shown by the model. In spite of the apparently complicated motion of the rotor the model spins quite freely, showing that substantially perfect balance has been achieved.

Figs. 2 and 3 show the model in two characteristic positions. In Fig. 2 the right hand compartment is at its maximum volume, while in Fig. 3 the compartment at the bottom is at minimum volume. The change in volume (corresponding to the "swept volume" in a conventional engine) can be calculated from the quoted dimensions as approximately 275 c.c. Thus, the model is somewhat larger than "life size" if compared with the N.S.U. prototypes (reported as 125 c.c.) but probably about the same size as some of the prototypes of Curtiss Wright who are working on larger engines than N.S.U.