IMPROVED EFFICIENCY IN 00-GAUGE MECHANISMS

By H. J. Stubbs

DESPITE the rapid growth of interest in 00-gauge, the standard of operation has remained very low and one or two enthusiasts, including myself, have been striving to improve matters. The ideal would appear to be—

1. Certain starting, running and stopping at the will of the operator.
2. Really slow running qualities.
3. Smooth and noiseless operation.
4. Sufficient power to handle trains of scale length.

All these qualities combine to demand a mechanism far better than those at present available.

Benefit of Higher Voltages

A step in the right direction was taken some 18 months ago by Mr. Alex F. Jackson of Manchester, who, after many years' experience with 1-gauge on 100 volts A.C. decided to enter the 00-gauge field. He was aware that, even with 12 volts, dirt on the track caused a great deal of poor control and so he adopted 24 volts as being safe to handle yet high enough to break down the insulation due to normal dirt on the rail surface.

Since then, many of us who have seen his demonstration model have changed to 24 volts with amazing benefits. Perhaps the biggest benefit is that, with brass or nickel-plated wheels on nickel-silver rail, no cleaning of the track is ever needed, also items one and two of the four ideal conditions mentioned above are readily attained if the mechanism is a reasonable one.

Windings

The use of 24 volts instead of 12 means that, for a given power, current consumption (amps.) is rather more than halved and this in turn means that finer wire can be used on the armature and consequently a greater number of turns of wire.

Pre-war mechanisms, and to a less extent, post war ones, have far too few turns of wire on the armature and this results in a fast-running mechanism, very heavy on current and with little power, especially at low speeds. Provision of armatures wound with many turns of fine wire, however, results in slow running with real power as my ideal conditions two and four, whilst at the same time lowering current consumption.

It has been found that many commercial mechanisms have more turns of wire on one armature limb than on another. The importance of getting precisely the same amount of wire on each limb cannot be too highly stressed. Failure to do so causes noisy running and bad sparking at the brushes, which will soon ruin the commutator.

Magnets

Modern magnets as used in 00-gauge mechanisms are nowadays fairly good as far as flux goes and the growing use of aluminium nickel alloy blocks with pole pieces is to be commended, but one very bad fault occurs all too often, viz. magnetic locking. Mr. E. H. Whittaker of Manchester has already drawn attention to this trouble which manifests itself in poor starting, the mechanism requiring almost full power from the controller before it will start. On starting it immediately races away at high speed unless throttled back and this behaviour, whilst giving poor control, has earned for 00-gauge locomotives the title of "animated mice." Several experts have tackled the problem and Mr. R. D. Pochin has suggested that the gap between the magnet poles should be slightly wider than the top of the armature limb, the pole itself subtending an arc of about 110°. This theory has been tried out on several mechanisms and it can be stated that magnetic locking has generally been reduced to negligible proportions by such methods. The majority of commercial magnets require to have a small amount of metal ground away from the poles as shown in Fig. 1 to come up to Mr. Pochin's specifications. No doubt exists in my mind that most commercial mechanism magnets embrace too much of the armature. A pre-war 12 volt Romford mechanism which had its magnet ground away $\frac{3}{64}$ in. each side was found to start on $1\frac{1}{2}$ volts instead of 8 volts, whilst the slow running was vastly improved and current consumption dropped.

Commutator and Brushes

The use of brass commutators is not recommended with 24 volts and copper should therefore be used in preference. This means using some form of carbon brush and highly satisfactory results have

(*Continued on page 83*)

been obtained with the carbon out of dry batteries. A better grade, in my opinion, is " Hard Morganite 8 " made by the Morgan Crucible Co. Some large brushes were obtained, made in this material and " pencil " type brushes $\frac{3}{32}$ in. diameter by $\frac{3}{16}$ in. long were turned from the large piece. These brushes, looking like lighter flints, were made a close slide fit in brass tubular brush holders and they were very lightly sprung with $\frac{3}{32}$ in. diameter coil springs wound from ·008 in. diameter spring steel wire. It is essential that these springs are as long as possible and contain as many turns as possible to ensure that they are really " weak." Most commercial brushes are far too heavily sprung and just cause unnecessary friction in the mechanism.

The results attained with " Hard Morganite 8 " brushes, which are actually electrolytic graphite, have been good at all voltages down to 2 and no wear appears to take place on the commutator. Whilst on the subjects of commutators and brushes, it has been found that sparking at the brushes is almost eliminated, and far smoother running obtained, by connecting electrolytic condensers to the value of 1000—2000 microfarads across the power unit output. Suitable condensers to the above value may be picked up for 5s. or so at stores dealing in Government Surplus equipment. Positive and negative terminals on these condensers *must* be connected to positive and negative respectively on the power unit and *not* vice versa.

Mechanical Efficiency

The foregoing notes have concerned the electrical side of the mechanism but it is in the improvement of the mechanical efficiency of the mechanism that the greatest rewards are found. The aims should be :

1. To cut down friction.
2. To cut down adverse torque or drag in the mechanism due to frictional resistance acting on a shaft or commutator of too large a diameter.
3. To provide adequate thrust bearings to absorb worm thrust without great frictional resistance.
4. To cut down noise (which represents loss of energy) to a minimum.

Friction

Friction can be cut down by the use of phosphor bronze for bearings and worm wheels (brass is hopeless) and by employing hardened silver-steel worms, lapped in with a fine abrasive (toothpaste is excellent for this purpose). The copper commutator and lightly sprung graphite brush are also an ideal combination in the campaign against friction.

Also, make sure that any bearing surfaces are really highly polished and fine bore or ream all bushes. Provide adequate oil holes to every bearing.

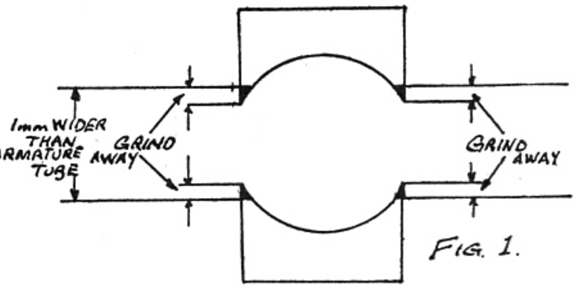

FIG. 1.

Adverse Torque

A certain amount of friction must, however, always occur and the greater the radius of any shaft, commutator or worm, the more power will be lost in overcoming the friction at the periphery. It is therefore imperative to keep shafts, worms and commutators as small as possible in diameter.

Thrust Bearings

The thrust along the armature shaft due to the worm is a lot greater than one would imagine and the pin point ended armature shafts running in a cone, which were a feature of pre-war mechanisms, suffered a great deal of power loss through the cone bearings grinding together like the well-known cone clutch. A device becoming more popular to-day is to use a plain sleeve bearing at each end of the shaft, with a $\frac{1}{16}$ in. steel ball at the end of the sleeve against which the shaft can run. If the end of the shaft is domed and hardened, this bearing is as fine a thrust bearing as any. A screw, bearing against the ball at one end is used to take up end play and this screw should be kept up tight, otherwise noise due to " chatter " in the bearing will result. Fig. 2 shows the scheme for this thrust bearing.

In the case of a mechanism in my possession, the shaft is stepped down to $\frac{1}{32}$ in. diameter, hardened and lapped and runs against a $\frac{1}{32}$ in. steel ball, the phosphor bronze bush itself being threaded for end adjustment. No trouble has been experienced although the bearings are really very fine. Without the brushes and magnet, the armature will spin for almost a minute before coming to rest.

Noise

The biggest cause of noise in any mechanism, in my opinion, is loose bearings and here lies the disadvantage of a sleeve bearing. As the armature spins at 10,000 or more revolutions per minute it sets up " chatter " in the bearing if there is any play. To avoid this I intend to use a split, outside tapered bush which can be forced into a tapered seating which will close it slightly to compensate for any wear. Whilst I have no doubt as to the ultimate success of this method, I cannot yet speak from experience in its use.

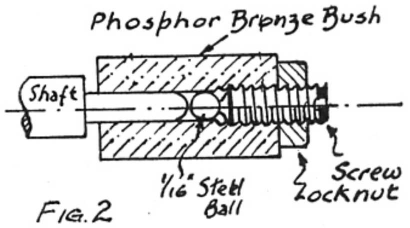

FIG. 2

Another cause of noise is " chatter " of the brushes on the commutator slots. The only remedy here is to keep the slots as narrow as possible (I use a ·007 in. slitting saw) and to fill the slots with mica, keeping the mica just flush with the commutator surface. Pencil type brushes of the type mentioned earlier are, however, extremely quiet.

The armature slots passing the magnet poles are likely to have a " siren " effect and a great help in cutting this out is to sandwich the magnet between two thick brass plates and bore the whole lot together, or, if the magnet tunnel be finished and hardened, to bore out the plates to the same diameter, the idea being to provide a continuous tunnel in which the armature can run without siren effect. Needless to say, these side plates must be of brass or other non-ferrous metal. Space considerations might prohibit the use of this idea but that is a matter for ingenuity in the design of the mechanism.

Other points to watch in the fight against noise are that the motor might be mounted on rubber or, at least, ebonite, making sure that any fixing screws do not make metal to metal contact with both frames and motor. Mount bearing bushes in ebonite. See that armature and commutator run dead true and that the armature is mechanically balanced. Use involute gears and worms with as little backlash or " play " as possible.

Flywheels

A word about the use of flywheels may be of interest. It is now the practice among a few of us to fit flywheels made of lead, direct to the armature shaft. The flywheel should be as large as possible and to achieve this object the motor is often fitted in the tender. In one case, however, the motor fits into the tanks of a locomotive, the flywheel going into the bunker and being driven by a universally jointed shaft.

Good dimensions for a flywheel are—

Diameter	...	$\frac{15}{16}$ in.
Rim width	...	$\frac{7}{16}$ in.
Rim thickness	...	$\frac{3}{16}$ in.

The rim is cast in lead on to a brass disc which serves as the " web " of the flywheel, a boss being fixed in the centre. The flywheel is setscrewed to the shaft by two 12 B.A. screws, diametrically opposed to preserve balance. Needless to say, the flywheel is accurately turned and polished after casting.

Using such flywheels, locomotives regularly run without embarrassing jerks, stops, etc. at speeds down to a scale 1 m.p.h. and, if switched off from full current, they will coast as much as four feet. It is impossible to get " jet propelled " starting as, no matter how you switch the juice on, the flywheel will not be hurried and takes its time to speed up. Control is much more fun because unless the engine is handled properly, as a real engine, it is liable to pile up against the buffers, the flywheel having taken complete control.

It must, however, be stressed that the flywheel does not, itself, cancel out the results of bad design in a motor. The motor must be capable of slow, sweet running on the bench, before the flywheel is fitted, the flywheel merely smoothing out small speed fluctuations and providing useful inertia which the motor would not otherwise possess. It also ensures more railwaylike operation.

Armature Diameter

The EM-gauge fine scale (18 mm.) now permits a $\frac{5}{8}$ in. diameter armature to run between the wheel backs. The benefits of using a $\frac{5}{8}$ in. diameter armature rather than a $\frac{1}{2}$ in. diameter one cannot be too highly stressed. There is a great increase in power, whilst the motor runs slower and therefore quieter. It is possible to have five poles without sacrificing turns of wire. For mechanisms where the armature has to lie in a confined space, it is better to so arrange it to allow of large diameter rather than length. In fact a $\frac{5}{8}$ in. diameter tripolar armature only ·20 in. long will hold as much wire as a $\frac{1}{2}$ in. diameter armature $\frac{1}{2}$ in. long, but the former has far more inertia, or " flywheel effect," runs much slower, and has a greater torque than the latter.

Gear ratios

For normal work, all types of engines should have overall gear reductions of

$\frac{1}{2}$ in. diameter armature	35 : 1
$\frac{5}{8}$ in. diameter armature	30 : 1

It is better to achieve this reduction at one stage, i.e. by a worm and wheel, since every additional gear means loss of efficiency and an increase in noise. It is also better to use a two start worm since gear efficiency is thus increased and, in fact, a two start worm gear properly made is very often reversible, i.e. the wheel will drive the worm. The snag is that with a two start worm, twice the number of teeth are required on the wheel, compared with a single start worm and this makes the worm wheel rather large. The answer of course is to use a very fine pitch and I would recommend a worm pitch of 24 threads to the inch as being easy to cut on an amateur's lathe. The best form is as laid down in War Emergency British Standard 978—1941 "Gears for Clockwork Mechanisms," the "minimum backlash" involute tooth form being ideal. This form for 24 T.P.I. gives a tooth about $\frac{1}{32}$ in. deep and a 70 tooth (i.e. 35 : 1) two start worm wheel comes to just under 1 in. diameter, i.e. it can only be used with express type locomotives. A single start wheel can of course be used with any locomotive.

In General

The foregoing notes, whilst being very sketchy, are intended to convey the essence of quite a deal of thought and research. It may be thought that the notes are a waste of good newsprint, and maybe they are, but readers may be assured that such mechanisms as have been built, bearing the above points in mind, have given results which we feel cannot be equalled by any mechanisms at present on the market, the real benefit of course being improved and much more realistic operation. If there is any general call for further information, I shall be delighted to submit the actual drawings of a mechanism incorporating all the foregoing points. In the meantime, I can do no better than quote brief details of two existing and successful mechanisms.

1. 24 volt mechanism fitted in tender of L. & Y. Aspinall 0-6-0 built by A. F. Jackson.
   Drive—Flexible shaft to locomotive.

This mechanism employs a Romford Magnet and a $\frac{1}{2}$ in. diameter 3-pole armature made from Romford stampings. Each limb of the armature contains 300 turns of 42s gauge "Lewmex" covered wire. The commutator is of copper, and bearings, brush springing, flywheel, etc. are generally as in the foregoing notes. The worm runs against a ball thrust bearing at each end, made up of three $\frac{1}{32}$ in. diameter steel balls in each case. The ratio is, I believe, 35 : 1. As to performance, the locomotive will run under perfect control at a scale 2 m.p.h. The maximum speed is a scale 50/60 m.p.h. The locomotive is extremely heavy and the tender also bears on the rear of the locomotive footplate; nevertheless, slipping against buffer stops takes place at about 12 volts, the maximum current then being about ·3 amp. Normally, the locomotive takes only about ·15 amp. and it will run light on 4 volts ·05 amp. A 5-pole armature, wound with 300 turns per limb of 44s gauge and run in the same type of motor gives even better results.

2. A 24 volt mechanism for a L.B. & S.C. "Terrier" tank, built by myself. This mechanism fits entirely in the tanks of the engine and measures only 1 in. by $1\frac{3}{16}$ in. by 1 in. overall including the gearbox. It has a $\frac{5}{8}$ in. diameter by ·2 in. long 3-pole armature with 430 turns of "Lewmex" covered 42s gauge wire per limb. The worm, which is hardened, is $\frac{5}{32}$ in. diameter, 24 threads per inch involute as recommended in the article. There is also a $1\frac{1}{2}$: 1 spur reduction of identical tooth dimensions making an overall ratio of $37\frac{1}{2}$: 1 which is a bit too much since the locomotive has a maximum scale speed of only 42 m.p.h. There is no flywheel owing to lack of space, otherwise the mechanism is as recommended in this article, the magnet being a block of Magnet Alloy cut from an Eclipse magnet and fitted with mild steel pole pieces. On a bench test the mechanism will start and run on 2 volts ·02 amp. and on the track it moves off at a scale 3 m.p.h. on 3 volts ·04 amp. With 3 lb. weight on top it slips at about 12 volts.

Both the above mechanisms are 2 rail, EM-gauge, and are sprung, using phosphor bronze horn blocks. The axles are split in the centre and insulated, the current getting to the mechanism via the bearings. There are thus no rubbing collectors and this is really the secret of the slow, easy running of the mechanisms when on the track.

A point to note about these mechanisms is that, on 24 volts, they require at least 500 ohms resistance in the controller which is equal to about ten commercial controllers in series or eight 1000 watt fire elements. For 12 volt operation 130 ohms should be enough, but it must be realised that more efficient mechanisms call for something much in advance of the average controller in use to-day. On a bench test, 800 ohms was insufficient to bring the "Terrier" mechanism to a halt.

In conclusion, it is realised that many enthusiasts will not have the equipment or engineering training to carry out the construction of mechanisms on the lines detailed, but it is hoped that the trade may consider some of the points as being worthy of attention, whilst the realisation that better results may be attained may bring forth an insistence upon higher quality which can do only good for the hobby. I shall welcome any criticism or further information and, if the demand be great enough, I would be prepared to prepare articles on the making of the various bits and pieces of mechanisms together with notes on armature winding.

BOX CARS

(*Concluded from page 93*)

Last but by no means least come the trucks (bogies), the usual patterns being the Battendorf or Archbar. Should you have friends in America you know the answer but if you have difficulty in getting trucks or for that matter scale buck-eye couplers write to Peter Densham, 67, Sussex Road, North Harrow, Middlesex, marking your envelope in the top left hand corner "Box Freight".

Next time—flats, gondolas and hoppers.