EDDY CURRENTS

A. S. Lipson brings you the life of Eddy Current, last known to be circulating in the region of transformers.

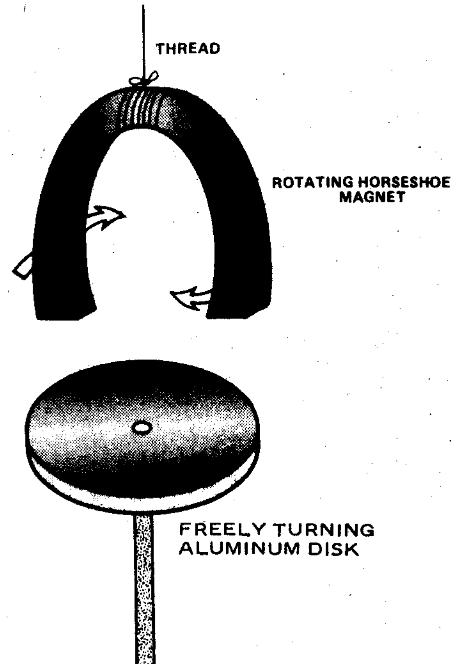


Fig. 1a. The rotating magnet induces eddy currents in the aluminum disc.

THE BRANCH OF PHYSICS now known as electromagnetism can be said to have been born in 1819. It was in that year that Professor Oersted of the University of Copenhagen discovered that electricity and magnetism are related — that a current flowing in a conductor produces a changing magnetic field — was discovered simultaneously, and quite independently, by Faraday in England and Henry in America.

Both of these effects are used, for example, in the transformer; an alternating current in a coil creates a changing magnetic field, which, in turn, is used to produce an EMF (and hence a current, should a circuit be connected) in another coil. However, rather less people are aware of another, very closely related, and extremely interesting, effect — the phenomenon of eddy currents . . . .

What's In A Name

Magnetic fields are not usually quite as selective as we would like them to be. A changing magnetic field will not only produce an EMF in any coils in its vicinity, but it will also produce EMFs, and hence currents, in any conductor around — even any old lumps of metal that may be just hanging about. These currents don't actually go anywhere — they just circulate round and round within the conductors, like eddy currents in a liquid. Hence the name — eddy currents.

Since eddy currents are the result of induced EMFs in conductors and because resistances within conductors can be very small, the currents can on occasion be quite sizeable, and so the effects produced by them can be very significant. In fact, eddy currents are far more than just a scientific curiosity. Depending on exactly where they are, and what they are doing, they can be either a curse or a blessing. However you view them, though, they are an interesting phenomenon, and can produce some fascinating effects, not all of which are totally useless!

Counting Your Blessings . . . . . .

One of the more striking experiments on eddy currents is shown in Fig. 1a. A horseshoe magnet is suspended on a thread, above an aluminum disc which is itself free to turn about its centre. If the magnet is now spun round, the aluminum disc starts to rotate with it (although it never quite catches up with the magnet). Similarly, if you spin the aluminum disc, the magnet above it also starts to turn. This obviously cannot be due to ordinary magnetic effects — aluminum is non-magnet, and if you try to pick up the disc with the magnet, you will find that you are unable to. It is apparent that something funny is going on. (No, air currents aren't dragging the disc round when the magnet rotates — you can put a sheet of paper between the two, and the effect still works!)

Field Study

The relative movement between the magnet and disc is inducing eddy currents in the aluminum. These, in turn, create other magnetic fields, and it is these that cause the magnet and disc to move together — the magnetic field of the magnet interacting with the fields caused by the eddy currents (sounds a bit like pulling yourself up by your bootstraps, but it's correct) An interesting follow-up to this experiment is to replace the disc with one cut as shown in Fig. 1b. The slots tend to get in the way of the eddy currents and prevent them from flowing, so such a disc is not dragged round so easily by a magnet (which is another way of showing that air currents don't do the work — the slots shouldn't make any difference to them).

Interestingly enough, this apparently insignificant effect actually has some practical application. It is used, for instance, in the normal car speedometer! The rotation of the wheels is transmitted, by various means, to a magnet, which itself rotates, with a speed proportional to that of the wheels. This rotating magnet induces eddy currents in an aluminium disc, (or its equivalent) and tries to drag it round. However, a spring is used to hold the disc, so it is unable to turn very far. The faster the car goes, though, the faster the magnet rotates, the greater the eddy currents, and the further round the aluminum disc is pulled. By attaching a little red or orange needle to this disc and seeing how far this needle rotates, we can work out how far the disc has turned, and hence the speed of rotation of the magnet. Thus, we find out the speed of the car. Yes, I wish I'd thought of it first, too.

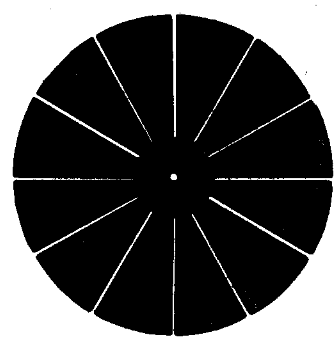
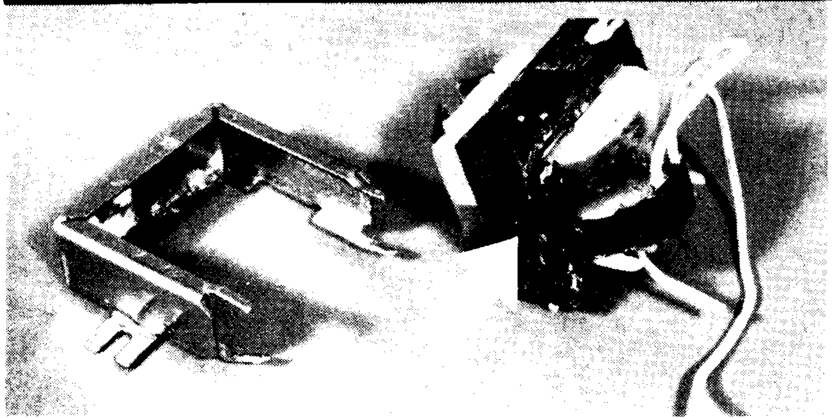
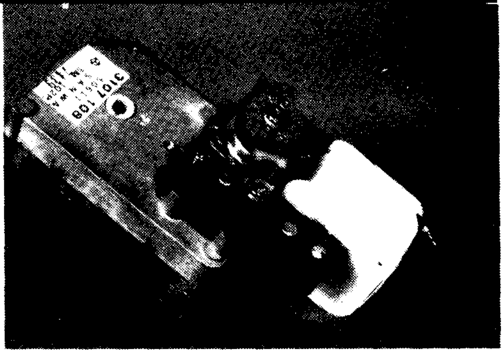


Fig. 1b. If the disc in Fig. 1a. is replaced with the one cut like this, the drag effect is greatly reduced, or even stopped.





Cutting Your Losses

Besides being useful, though, eddy currents can also be very annoying. They could justly be called the transformer designer's nightmare. The transformer is, basically, two coils, close together. However, in the middle there's a dirty great lump of metal (the core) and it doesn't just sit there doing nothing, with all those magnetic fields about. No prizes for guessing what happens. It might not seem that eddy currents in the transformer core would be much of a problem, but they are, for two main reasons. Firstly, the eddy currents mean a loss of power in the transformer and hence reduced efficiency. It stands to reason that if power is being used to drive currents around in the core, then that much less power is going to be available for use from the secondary coil. The second problem is no less serious, especially in large-scale transformers. The power being wasted in the core, driving eddy currents round, quite naturally ends up as heat, and consequently transformers are liable to get very hot. indeed, large transformers, such as those on utility power grids, may be oil-cooled, to prevent overheating.

It is obvious that, in transformers at least, eddy currents are not wanted. So what can be done about them? Well, if you've ever taken an old transformer apart for the wire, or even just out of curiosity (naughty, naughty), you will probably have noticed that the core is not just one solid lump; it is built up of flat metal laminations. This is not because they make the cores out of flattened baked bean tins. The laminations are separated by varnish or paper of some other insulator and this greatly increases the internal resistance of the cores, reducing eddy currents. Hence, both the loss of power and the unwanted heating are reduced.

Even the heating effect of eddy currents can be put to use, though. It is used in the production of pure crystalline samples of conductors like metals or semiconductors — germanium, for example. The impure sample of the material is passed, in a crucible, through a coil, which has passing through it a high frequency alternating current. The magnetic field produced by this current induces eddy currents in the specimen and the heating effect is great enough to melt it! As the sample passes through the coil, the molten zone within it is carried to one end (Fig. 2). Impurities within the sample are accumulated in the molten zone and hence get taken to one end of the specimen. This end is later removed. What is left is a very pure, crystalline sample of the substance. So eddy currents can be surprisingly useful!

(Above) A small transformer with its frame removed. The arrow points to a loosened lamination. (Right) A synchronous induction motor. Eddy currents induced in the armature eliminate the need for expensive and noisy commutators. Motors like these are cheap and reliable but very inefficient.

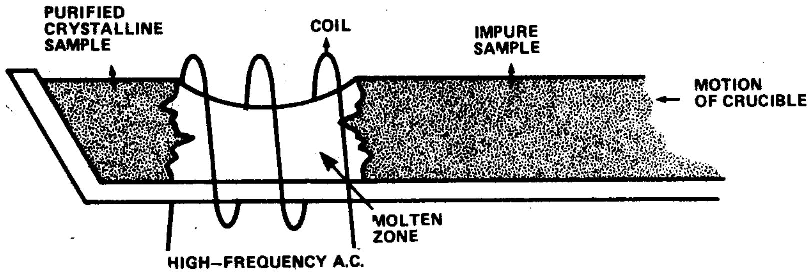


Fig. 2. The heating effects of high frequency AC can be put to good use in semiconductor material manufacture.

Footnote

There is one final point which must be at least mentioned in connection with eddy currents. This is the induction motor, an indispensible servant of industry. It depends for its operation on eddy currents . . . . . full explanation of that, though, is another story altogether. ●