DESCRIZIONE DI UNA MACCHINETTA ELETTRO-MAGNETICA

DEL DR. ANTONIO PACINOTTI

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DESCRIPTION

OF A SMALL ELECTROMAGNETIC MACHINE

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Translation of S. P. THOMPSON

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IN 1860 I had occasion to construct for the Cabinet of Technological Physics of the University of Pisa a model of an electromagnetic machine designed by me and which now I intend to describe. My special aim is to make known an electromagnet of a particular kind used in the construction of this machine, and which, besides the novelty which it presents, seems to me to be adapted to give greater regularity and constancy of action in such electromagnetic machines. Its form also seems to me convenient for collecting the sum of the induced currents in a magneto-electric machine.

In ordinary electromagnets, even when there is a commutator fitted to them, the magnetic poles are accustomed to appear always in the same positions, while on the contrary in the electromagnet which I am about to describe, by making use of the commutator which is joined to it, the poles may be caused to move in the iron subjected to magnetization. The form of the iron of such an electromagnet is that of a circular ring.

In order to conceive easily the operation and the mode of action of the magnetizing current, let us suppose that there is wound upon our ring of iron a copper wire covered with silk, and that; when the first layer has been completed, instead of continuing the coil by winding over that already wound, the metallic wire is closed on itself by soldering together the two ends which are near one another; we shall thus have covered over the ring of iron with a spiral, closed and insulated, having its turns wound always in one direction. Now, if we put into communication with the two poles of the battery two points of the metallic wire of this coil sufficiently distant from one another, the current will divide itself into two parts and will traverse the coil, in one part and in the other, between the two points of communication; and the directions which they take are such that the iron will become magnetized, presenting its two poles at the two points where the junctions of the current are. The straight line which joins these poles may be called the magnetic axis; and we shall be able, by changing the points of communication with the battery, to cause this axis to assume any position whatever transversely to the figure or circle of iron of the electromagnet, which for this reason I am pleased to designate as a *transverse electromagnet*. The two pieces of the magnet, at the two sides of the straight line (in our machine it is a diameter) drawn between the two junctions with the battery, may be considered as two opposed curved electromagnets, with their poles of the same name set facing one another.

To construct on this principle the electromagnet with which I have furnished the little electromagnetic machine, I took a ring of iron, turned, having, in the fashion of a wheel, 16 equal teeth, as indicated in Figure 1. (See the Plate). This ring is supported by four brass spokes *a a a a* (fig. 4), which unite it to the axle of the machine. Between tooth and tooth some little triangular prisms of wood *m* (figs. 1 & 4) leave spaces. By winding copper wire covered with silk in these spaces I have succeeded in forming between the teeth of this iron wheel as many insulated coils or electrodynamic bobbins as there are teeth. In all these coils, some of which are marked with *r*, (figs. 3 & 4), the wire is wound in the same direction, and each one of them contains nine turns. Every two consecutive coils, like those two marked $r\ r'$, are separated from one another by an iron tooth of the wheel and by the triangular piece or prism of wood *m m* (figs. 1, 3, 4). In passing from one of these coils to wind the succeeding one, I left free a loop of the copper wire by fixing it to the piece of wood *m* which separates the two coils. To the axle *M M* (fig. 3), on which the wheel thus constructed is mounted, I brought down all the loops which constitute the end of one coil and the beginning of the next, making them pass through convenient holes pierced in a wooden collar fixed round the same axle, and each of them is then attached to the commutator *e* (fig. 3) mounted also on the same axle. This commutator consists of a short cylinder of box-wood with two ranges of hollows, around the ends of the cylindrical surface, in which there are inlaid sixteen pieces of brass, eight above and as many below, the first alternating with the second, all concentric with the wooden cylinder, slightly projecting, and separated from one another by the wood. In figure *c* of the commutator the pieces of brass are indicated by the dark spaces. Each of these pieces of brass is soldered to the corresponding loop between two of the bobbins. Thus all the coils communicate with one another, each one being joined to the next by a conductor of which one of the brass pieces of the commutator forms a part; and hence by putting two of these pieces into communication with the poles of the battery by means of two metallic rollers, *k k* (figs. 3, 4) the current will divide itself, and will traverse the windings at both sides of the points whence the loops lead that are joined to the communicating pieces; and magnetic poles will be formed in the iron of the circle at *N S*. The poles of a fixed electromagnet *A B* act on these poles *N S*, and determine the rotation of the transverse electromagnet around its axis *M M*; since in it, even when in movement, the poles are always produced in the same positions *N S*, which correspond to the points of communication with the battery.

This fixed electromagnet, as figures 3 and 4 show, is composed of two cylinders of iron *A B* joined together by a yoke of iron *F F* to which one of them is fixedly screwed, while the other is fastened by a screw *G*, which permits them to be shifted along a groove, in order to move the poles of the cylinders *A B* nearer towards, or further from, the teeth of the wheel. The current from the battery, entering by the terminal *h*, passes by a metallic wire to the support *l* and from thence to the roller *k*, circulates through all the coils of the wheel and returns by the support l^1 which carries it by another copper wire to the coil which surrounds the cylinder *A*. Emerging from this it passes to the coil of cylinder *B*, and is brought back by another copper wire to the second terminal h^1.

I have found it very advantageous to join to the two poles of the fixed electromagnet two pole-pieces of soft iron *AAA*, *BBB*, each of which embraces, over more than a third of the circumference, the wheel which constitutes the transverse electromagnet; putting them sufficiently near to the teeth of the same, and bracing them together with brass yokes *EE*, *FF*, as may be seen in the horizontal projection (fig. 4). These pole-pieces are not shown in the vertical projection (fig. 3) of the machine, as they would have hidden too much the coils and teeth of the wheel. The machine works even when the current is passed only through the circular electromagnet, but it has less force than when the current passes also through the fixed electromagnet.

I made some experiments in measuring the mechanical work which the machine produced and the corresponding consumption of the battery.

These experiments were arranged in the following way:

The shaft of the machine carried a pulley *QQ* (fig. 3) which was surrounded by a cord which passed around a rather large wheel, and caused it to turn when the electromagnetic machine was in motion. The axle of this wheel was horizontal and a cord winding round it lifted a weight. At one end of the axle of this windlass was a brake loaded in such a way that the weight which was to be raised was almost sufficient to set in motion the whole apparatus including the little electromagnetic machine when not supplied with current. By this arrangement, when the machine works, the mechanical work absorbed by the friction is equal to that employed to raise the weight; and to have the total work done by the electromagnetic machine it sufficed to double that obtained by multiplying the weight lifted by the height to which it was raised. The mechanical work produced being thus evaluated, in order to know the consumption which took place in the battery in the production of this work, there was interposed in the circuit of the current a voltameter, containing sulphate of copper, the copper plates of which were weighed before and after the experiment.

I will give the numbers obtained in one of these experiments on the little machine with transverse electromagnet. This little machine, which had a wheel with a diameter of 13 centimetres, was moved by a battery of 4 small Bunsen elements, and it raised to 8.66 metres a weight of 3.2812 kilogrammes, including friction. Thus it accomplished a mechanical work of 28.415 kilogrammetres. The positive copper of the voltameter diminished in weight by 0.224 grammes; the negative copper increased by 0.235, so that, in the mean, the chemical work in the voltameter may be represented by 0.229 grammes. This number, multiplied by the ratio of the equivalent of zinc to that of copper, and by the number of elements of the battery, gives for the weight of zinc consumed 0.951 grammes. Hence to produce one kilogrammetre of mechanical work there are consumed in the battery 33 milligrammes of zinc. In another experiment made with 5 elements, the consumption was 36 milligrammes for every kilogrammetre. Although these results do not place the new model much above other small electromagnetic machines, nevertheless they do not seem to me bad when I reflect that in it there are defects of construction which do not ordinarily occur in other small machines of this class. Amongst these imperfections I ought to indicate that the commutator is made in brass, and is badly centred, so that the contacts do not all act sufficiently well.

The reasons which induced me to construct the little electromagnetic machine with the system described were the following: (1) In the disposition adopted the current never ceases to circulate in the coils, and the machine does not move by a series of impulses following one another more or less rapidly, but by a couple of forces which act continuously. (2) The circular construction of the rotating magnet contributes, together with the aforesaid mode of successive magnetization, to give regularity of movement and minimum loss of vis-viva due to shocks or friction. (3) In this machine it is not sought to bring about an istantaneous magnetization or demagnetization of the iron of the electromagnets, an operation which is opposed by the extra-currents and by the coercive force from which the iron can never be completely freed; but the only requirement is that every portion of the iron of the transverse electromagnet, exposed of course to suitable electrodynamic forces, should pass through the various degrees of magnetization successively. (4) The expanded pole-pieces of the fixed electromagnet, serving to act upon the teeth of the magnetic wheel, and embracing a sufficiently great number of them, do not cease to perform their actions so long as magnetism remains in them.

(5) The sparks are increased in number but are much diminished in intensity, since there are no strong extra-currents at the opening of the circuit which remains always closed; and only while the machine is working is an induced current continuously directed in a sense opposed to the current of the battery.

It seems to me that the value of this model is enhanced by the fact that the machine can be readily transformed from an electromagnetic machine into a magneto-electric machine, yielding continuous currents. If in place of the electromagnet *AB* (figs. 3, 4) there were put a permanent magnet, and the transverse electromagnet were made to revolve, there would be in fact a magneto-electric machine which would give an induced current continuously directed in the same sense. To find the most convenient position of the contacts upon the commutator, whereby to collect the induced current, we observe that on the movable electromagnet opposite poles are formed by influence at the extremities of a diameter in presence of the poles of the fixed electromagnet. These poles NS maintain a fixed position, even when the transverse electromagnet rotates about its axis: hence, as respects the magnetism, and consequently also as respects the induced currents, we may consider or suppose the copper wires to spin round in rows upon the circular magnet while the latter remains motionless. To study the induced currents which are developed in such coils let us take into consideration one of these in the various positions which it can assume. When going from the pole N towards the pole S, there will be developed in the coil a current directed in one sense until it has arrived at the middle point a; from this point forward the current will take an inverse direction. Then proceeding from S towards N, until we have arrived at the middle point b the currents will maintain the same direction as they had between a and S: after b again they will be inverted in direction, resuming the direction which they had between N and a. Now since all the coils communicate with one another, the electromotive forces in one given direction will be added together, and will give to the total current the disposition indicated by the arrows in figure 2; and to collect it the most convenient positions for the contacts will be *a, b*: or rather the contacts should be placed on the commutator at right-angles to the line corresponding to the magnetism of the electromagnet. The induced current varies its direction, changing its sense with the sense of the rotation. And as respects the commutator, when the contacts are upon the diameter corresponding to the line of magnetism, they will collect no current which ever way the electromagnet revolves. Starting from this position, on displacing them to one side there will be produced a current directed in a sense contrary to that which would be obtained by displacing them to the other side.

To develope an induced current by the machine so constructed I placed the opposite poles of two permanent magnets near to the magnetic wheel, or I magnetized by a current the fixed electromagnet which is there, and I caused the transverse electromagnet to revolve about its axis. Equally in the first or in the second mode I obtained an induced current, continually directed in the same sense, which showed on a galvanometer a considerable intensity even after having traversed some sulphate of copper or some water acidulated with sulphuric acid. Although it is understood that the second mode may not be convenient, it remains an easy matter to place a permanent magnet in lieu of the temporary magnet *AFFB*; and then the magneto-electric machine which results will have the advantage of giving induced currents, all directed in the same sense, and added together, without need of any mechanical organs to separate them from others which are opposed to them, or to bring them into concordance with one another. And this model shows well how the electromagnetic machine is the converse of the magneto-electric machine; since in the former by passing through the coils an electric current, introduced through the terminals $l\ l'$, there is obtained rotation of the wheel and mechanical work; and in the latter by employing mechanical work to make the wheel revolve one obtains by agency of the permanent magnet a current which circulates through the coils, and passes to the terminals to be supplied to the bodies on which it ought to act.

(Translation of S. P. Thompson).