United States Patent

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[33] **Italy**
[31] **828,353**

[54] **HIGH-SPEED ELECTROMAGNET**
4 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **335/249,** 335/279

[51] **Int. Cl.** **H01f 7/12**
[50] **Field of Search** 335/243, 249, 251, 279

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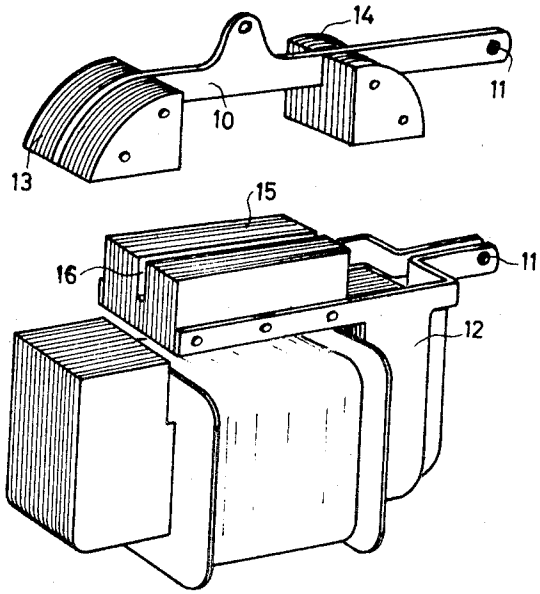
ABSTRACT: An electromagnetic structure including a movable armature and having additional airgaps provided in the magnetic loop so that the transit time from rest position to energized position is decreased.



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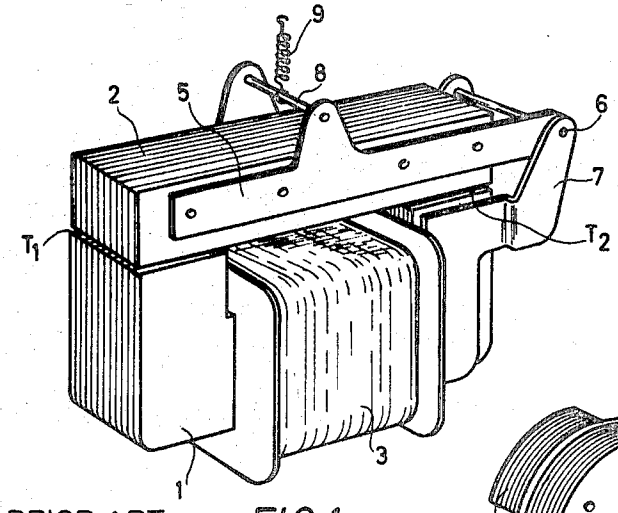
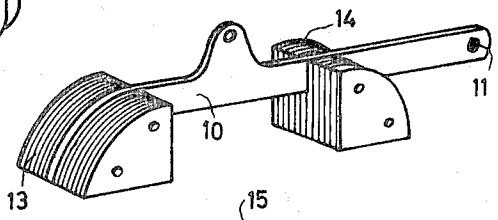


PRIOR ART FIG. 1



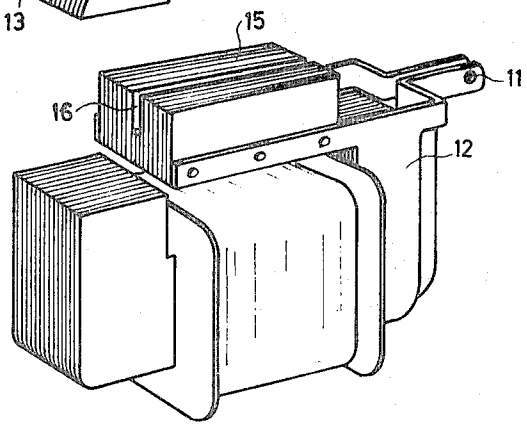


FIG. 3

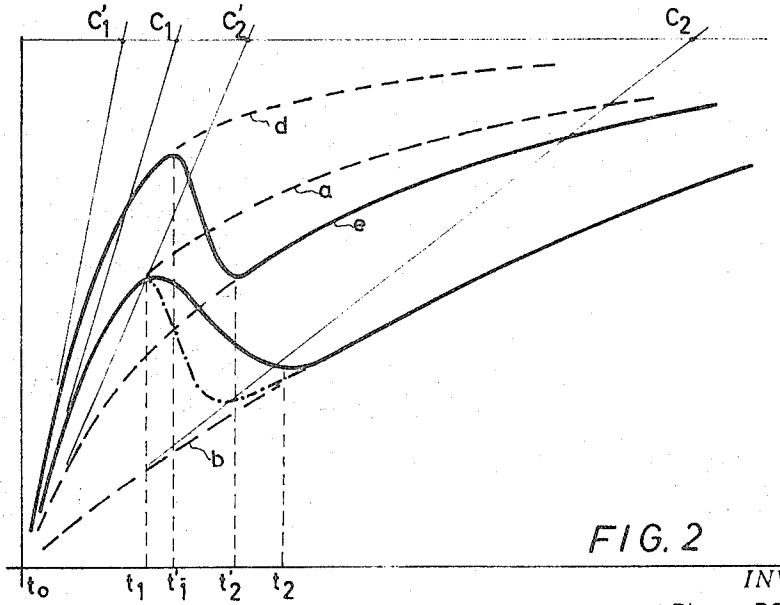


FIG. 2

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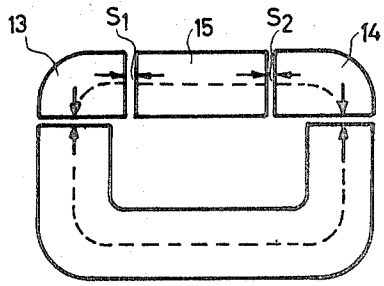


FIG. 4

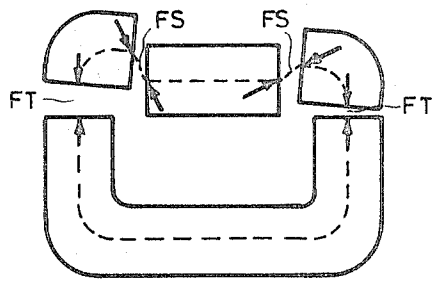


FIG. 5

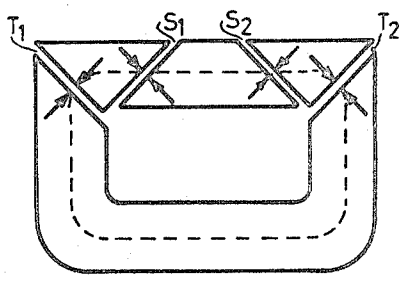


FIG. 6

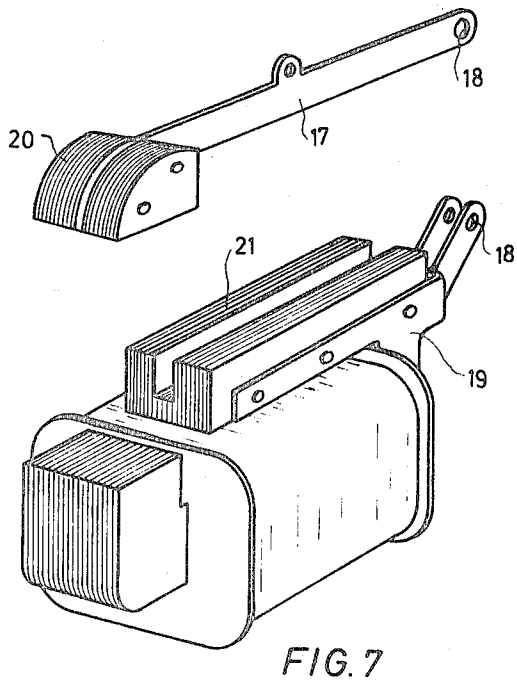
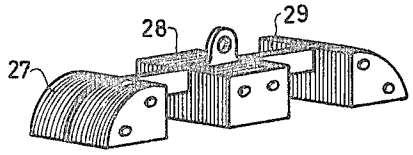


FIG. 7



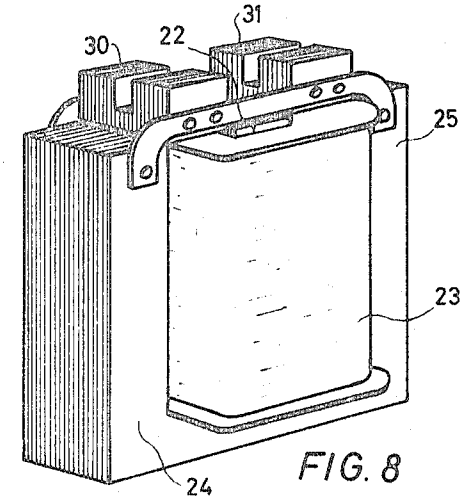


FIG. 8

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HIGH-SPEED ELECTROMAGNET

The invention relates to an electromagnet operating at high speed, and more particularly to the type usually employed for actuating the print hammers in high-speed printers, such as are used in connection with electronic data handling and transmitting apparatus.

The electromagnets known in the prior art generally comprise a U-shaped magnetic core on which the energizing coils are wound, and a movable armature which forms the magnetic yoke closing the magnetic path of the core. As a consequence, the armature has a substantially high mechanical inertia, which reduces the speed of its motion. In addition, when the electromagnet is deenergized, the airgap between core and armature is much wider than in the operated condition. The initial force acting on the armature at rest, is much lower than that acting in the operated condition, for the same value of current. Therefore the initial acceleration of the armature is relatively small, and reaches the maximal value only at the end of the travel. These conditions are unfavorable to the use of such electromagnets for controlling the motion of the hammers in printing apparatus, and more particularly when the high speed of the armature is more important than a very quick response.

In fact, the control device of the electromagnets of the high-speed printers can compensate for a small delay in the operation by suitably anticipating the energizing action, whereas it is important that the armature reaches its maximum speed as soon as possible to ensure a sharp and precise impact of the character on the print medium.

This object is attained, in an electromagnet according to the invention, by a special construction of the armature, whereby the magnetic yoke comprises at least a fixed portion and at least a portion movable with the armature. A substantial reduction of the inertia of the armature is thus obtained; in addition, the presence of at least an additional airgap may be used to control the variation of the moving force during the travel of the armature, in order to increase the average speed.

These and other features and advantages of the invention will appear more clearly from the following detailed description of a preferred embodiment thereof, with reference to the annexed drawings, in which:

FIG. 1 shows an electromagnet constructed according to the prior art.

FIG. 2 shows diagrams of the energizing current under different conditions.

FIG. 3 is an exploded view in perspective of an electromagnet formed according to the invention.

FIG. 4 is a schematic representation of the magnetic path of an electromagnet constructed according to the invention, in operated condition.

FIG. 5 is the schematic representation of the same in a rest position.

FIG. 6 is a schematic representation of an alternative disposition of the airgaps.

FIG. 7 shows a variant of the invention.

FIG. 8 shows another variant of the invention.

An electromagnet constructed according to the prior art is shown in FIG. 1. It comprises, primarily, a U-shaped core 1, usually consisting of juxtaposed sheets of ferromagnetic material; a coil 3 wound on the core; an armature 2, made of ferromagnetic material, fastened to a movable frame 5, which is hinged at point 6 to a fixed frame 7, fastened to the core 1. A restoring spring 9 is hooked to a bar 8 mounted on the movable frame, and its opposite extremity is hooked to a fixed point, not shown. The spring operates to maintain the armature at a distance from the core.

Appropriate adjustable abutment means, not shown, limits the maximal distance of the armature from the core, thus defining a maximal value T_{max} of the total airgap, which is the sum of two partial airgaps T_1 and T_2, facing the vertical arms of the U-shaped core.

When the electromagnet is energized, the armature is attracted by the core against the action of the restoring spring, and moves into the operated position, showing a minimum value T_{min} of the total airgap. This value is usually determined by a very thin layer of nonmagnetic material interposed between the armature and the core.

The characteristics of the motion of the armature during its travel may be inferred with sufficient precision by the oscilloscopic inspection of the energizing current.

With reference to FIG. 2, curve *a* represents how the current increase, if a constant voltage source is applied at instant t_o and the armature is fixedly held in the rest position, that is, at maximal airgap T_{max}. The curve is an exponential one, having a time constant $C_1=L_1/R$ wherein R is the total resistance of the electrical circuit, and L_1 the total inductance of the magnetic circuit at maximal airgap.

Curve *b* represents the current in the case that, all other conditions being the same, the armature is fixedly held in the operated position. The exponential curve *b* has a larger time constant $C_2=L_2/R$, L_2 being the inductance of the magnetic circuit at minimal airgap T_{min}, and therefore being larger than L_1.

If the armature is free to move, and the current supply is initiated at time t_o, the current firstly follows the curve *a*, as long as the armature remains in the rest position. At time t_1, when the armature starts moving, the airgap diminishes, and the consequent increase of the flux causes a voltage opposite to the current direction, which generally causes the current to decrease. At time t_2, when the armature has definitely reached the operated position, the current again begins to increase as shown by curve *b*.

The interval t_o–t_1 defines the response time of the electromagnet, and the interval t_1–t_2 the transit time of the armature.

It has been found that, for electromagnets operating the print hammers of high speed printers, it is of primary importance that the transit time t_1–t_2 be reduced to a minimum in order to provide that the armature moves with the highest possible speed, resulting in a sharp and precise impression of the characters.

This is obtained, according to the invention, by substantially reducing the moving mass of the armature, while maintaining substantially the same dimensions and characteristics of the magnetic circuit.

Referring now to FIG. 3, which shows an exploded view of an electromagnet constructed in conformity with the invention, the armature comprises, primarily, a rigid arm **10**, hinged at **11** to a fixed frame **12**. The arm **10** has no magnetic function, and therefore does not have to be made of magnetic material. Two portions **13** and **14** of the magnetic path closing yoke are fastened to it. The closing yoke is completed by a fixed portion **15**, having a channel **16** into which arm **10** may enter and be contained. In the operated position, the portions **13** and **14**, movable with the armature, are aligned with the fixed portion **15**. In this condition the magnetic path of the described electromagnet differs from the path of the prior arc electromagnet by including two additional airgaps S_1 and S_2, as shown in FIG. 4. It may be seen that the forces acting on the magnetic surfaces bounding these airgaps have a zero component in the direction of the allowable motion and therefore, they do not affect in this position, the behavior of the armature.

The movable mass of the armature, in the described electromagnet, is substantially less than the prior art electromagnets. This causes a reduction of the transit time, and, all other conditions remaining the same, the curve of the current would be that shown by the dot-and-dash portion of the lower curve in FIG. 2.

However, the additional airgaps S_1 and S_2 increase the reluctance of the magnetic circuit. As a sequence, the currents for armature held at rest and in the operated conditions should vary as shown respectively by curves *d* and *e*, having reduced time constants, respectively C'_1 and C'_2.

This should have the effect of diminishing both the response time and the transit time. However, the value of the current

needed for a flux capable of initiating the movement of the same armature is larger in view of the increased reluctance. If the dimensions of the additional airgaps S_1 and S_2 are held proper limits, the actual shape of the current curve is the upper one as shown in FIG. 2, and the response time $t_0-t'_1$ is not substantially larger than the response time $t_0-t'_1$, whereas the transit time $t'-t'_2$ is considerably less than the transit time t_1-t_2.

FIG. 5 shows, in an exaggerated form, the relative positions of the movable and fixed portions of the yoke, in the rest position. As may be seen, when the coil is energized, a flux is established along the indicated path, and the forces resulting on the bounding faces of the additional gaps have an oblique direction with respect to said faces, which results in a component in the direction of motion cooperating with the forces acting on the main gaps. This additional "sucking" force rapidly decreases as the armature moves, to become zero in the operated position. Therefore it is effective in increasing the acceleration of the armature in the initial phase, when the force acting on the main gap is at a minimum, thus increasing the average speed of the armature and decreasing the transit time.

By similar considerations it may be seen that the direction and disposition of the additional and of the main airgaps may be arranged in such a manner as to obtain unexpected results in the form of the variation of the force during the motion of the armature.

FIG. 6 shows one of such alternative arrangement, wherein the four airgaps T_1, S_1, T_2, S_2 are symmetrically located with respect to the direction of the motion of the armature.

FIG. 7 shows a variant to the preferred embodiment, wherein the bar **17** is hinged at **18** to the fixed portion **19** and carries only one portion **20** of the magnetic path closing yoke, the remaining portion **21** being fixed to the frame and fastened to the magnetic core. There is a single active airgap and a single additional airgap, thus obtaining a further reduction of the inertia of the armature, as well as of the reluctance of the magnetic circuit, and, in addition, a very simple mechanical structure.

FIG. 8 shows how the invention may be embodied in the case of an electromagnet of the type wherein the fixed magnetic core is formed by a central member **22** carrying the coil **23** and by two later "legs" **24** and **25**.

In the embodiment according to the invention, the armature comprises three movable portions **27**, **28** and **29** of the magnetic path closing yoke, whereas the two portions **30** and **31** of the yoke are fixed.

There are three main gaps and four additional airgaps. The additional "sucking" force acting on the additional gaps is particularly effective in this case.

I claim:

1. An electromagnet comprising a fixed ferromagnetic core, a coil wound on this core and effective in generating a magnetic flux in a closed circuit comprising said core; a ferromagnetic yoke for closing said magnetic circuit externally to said core along a low reluctance path and spaced from said core by at least a first planar airgap, said yoke being comprised of at least a portion fixed with respect to said core and movable portion separated from said fixed portion, a plane surface of said movable portion being opposite and substantially parallel to a plane surface of said fixed portion to define a planar second airgap between said opposed surfaces the plane of said second airgap being substantially perpendicular to the plane of said first gap, and mechanical linkages constraining the movement of said movable portion in a direction substantially perpendicular to the plane of said first gap.

2. The electromagnet of claim 1 wherein the movable portion of said yoke comprises a plurality of movable portions and a rigid member to which said movable portions are fastened to form a solid assembly.

3. An electromagnet comprising normally spaced apart fixed and movable ferromagnetic portions juxtaposed to provide a closed magnetic circuit path, said fixed portion being provided with a coil for receiving electric current to generate magnetic flux in said closed circuit for attracting said movable portion to said fixed portion, a first plane surface of said movable portion being opposite and substantially parallel to a first plane surface of said fixed portion to define a planar first airgap between said opposed first surfaces and perpendicular to said magnetic flux path, a second plane surface of said movable portion being opposite and substantially parallel to a second plane surface of said fixed portion to define a planar second airgap between said opposed second surfaces and perpendicular to said magnetic flux path, and means for supporting said movable portion for movement in a direction substantially perpendicular to the plane of said first airgap, the plane of said second airgap being substantially parallel to the allowable direction movement of said movable portion.

4. An electromagnet comprising normally spaced apart fixed and movable ferromagnetic portions juxtaposed to provide a closed magnetic circuit path, said fixed portion being provided with a coil for receiving electric current to generate magnetic flux in said closed circuit for attracting said movable portion to said fixed portion, a first plane surface of said movable portion being opposite and substantially parallel to a first plane surface of said fixed portion to define a planar first airgap between said opposed first surfaces and perpendicular to said magnetic flux path, a second plane surface of said movable portion being opposite and substantially parallel to a second plane surface of said fixed portion to define a planar second airgap between said opposed second surfaces and perpendicular to said magnetic flux path the planes of said first and second airgaps being mutually perpendicular to each other, and means for supporting said movable portion for movement in a direction perpendicular to the plane of said first airgap.