A magnetic printing head, for selectively magnetizing regions of magnetic recording media moving transversely therepast, has an elongated comb-like member of magnetizable material. Each of a multiplicity of slots in the member contains conductor means energizable to carry a flow of current for generating a magnetic orientation field between two adjacent comb-tooth tips and transverse to the direction of media movement. The conductor means in each slot may comprise at least a pair of independently energizable conductors for generating the orientation field responsive to coincident flows of current therein, preferably selected by matrix techniques.

12 Claims, 7 Drawing Figures
TRANVERSE RECORDING HEAD FOR MAGNETIC PRINTING

BACKGROUND OF THE INVENTION

The present invention relates to magnetic printing and, more particularly, to a novel magnetic recording head for selectively magnetizing regions in a belt of magnetizable material traveling in a direction transverse to the elongated dimension of the printing head.

Magnetic printers may conveniently utilize a belt of magnetizable material traveling past an elongated printing head; regions in the magnetizable material of the tape are magnetized responsive to each of a serially arranged multiplicity of magnetic fields generated by the printing head to impart information to the belt for printing purposes. The magnetization patterns on the belt subsequently cause magnetic "ink" to be transferred to the belt and subsequently to a medium, such as a paper sheet and the like, for permanent recording of the data patterns required.

Known magnetic printer recording heads are generally difficult to fabricate, in that the elongated magnetizable element requires precision machining and a relatively large number of windings (about 1600 individual windings for a 16 inch long printing head capable of recording 10 characters per inch with 10 recordable, sequentially aligned recording positions per character) must be used, each being part of a complex winding pattern, resulting in low yield. The yield is further reduced in recording heads of the type magnetizing the belt in the direction of movement (as disclosed, e.g., in pending U.S. application Ser. No. 716,087, filed Aug. 20, 1976 and assigned to the assignee of the present invention) which printing head, while offering advantageously performance factors, requires winding of wire arrays with multiple orthogonal directional offsets to achieve the windings for each data position. It is desirable to retain the relatively high performance of such a magnetic printing head while increasing yield and decreasing fabrication costs.

BRIEF SUMMARY OF THE INVENTION

In accordance with the invention, a magnetic recording head for selectively magnetizing regions of a magnetizable recording medium in a direction transverse to a direction of movement of the recording medium past the printing head, comprises an elongated member fabricated of magnetizable material and having a multiplicity of substantially equally spaced slots formed into an edge thereof closest to the moving magnetic medium. At least one conductor carries a flow of electric current through each slot of the comb-like elongated member to cause formation of each of a plurality of magnetic fields, each serially arranged adjacent to the open end of the associated slot and along the elongated dimension of the member, to magnetize a correspondingly small portion of the adjacent magnetic medium in a desired direction. The orientation field may be generated responsive to matrix-coincident flows of current in at least a pair of independently energizable conductors placed in each slot between a pair of adjacent comb-teeth; at least the field-forming portions of the conductors extend substantially in the direction of recording medium travel, whereby the magnetic field between two adjacent comb-teeth is transverse to the direction of travel of the overlying magnetic medium. In the simplest embodiment, an independently energizable conductor in each slot carries a flow of current therethrough, e.g. a linear array of 1600 slots requires 1600 individual and independent conductors. Thus, each embodiment of the novel head of the present invention writes transverse to the direction of belt travel.

In one preferred embodiment, the multiplicity of slots is divided into a plurality of word groups, each having an equal number of slots assigned thereto, with each slot of a word group containing one of a first plurality of word lines; a second plurality of digit lines are arranged whereby each digit line is contained in a similarly ordered single slot of each word-grouped block of slots. Each of the word and digit lines is wound in bifilar fashion, whereby the direction of winding of a conductor in sequential slots is alternated, to minimize the inductance of each of the word and digit lines, and facilitate higher printing speeds.

In another preferred embodiment, each of a pair of flexible insulating substrates is arranged along an opposite side of the elongated member to support conductive interconnection patterns including conductive portions emplaced within each slot and utilizing "zig-zag" conductor patterns to achieve alternating directions of current flow in adjacent slots to minimize undesirable magnetic effects.

Accordingly, it is one object of the present invention to provide a novel magnetic printing head for selectively magnetizing regions of an overlying magnetizable medium in a direction transverse to the direction of medium travel.

It is another object of the present invention to provide a novel transverse magnetic printing head utilizing a coincidence matrix conductor array.

It is still another object of the present invention to provide a novel transverse magnetic printing head having a substantially reduced inductance associated with any current-carrying conductor thereof.

It is a still further object of the present invention to provide a novel transverse magnetic printing head having means for supporting current-carrying conductors without requiring winding of a conductor about a magnetizable member.

These and other objects of the present invention will become apparent upon a consideration of the following detailed description and the corresponding drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of the magnetizing field generating elements of a novel transverse magnetic printing head in accordance with the principles of the invention, and illustrating the operating principles thereof;

FIG. 1a is a perspective view of a portion of the mechanical configuration of one embodiment of a novel transverse magnetic printing head;

FIG. 2 is a schematic side view of the elongated member and several of the current-carrying conductors of a matrix-driven embodiment of our novel transverse magnetic printing head and useful in understanding the operation of the present invention;

FIG. 3 is a perspective view illustrating the fabrication of a laminated, elongated magnetizable member for use in the transverse magnetic printing head of the present invention;

FIGS. 4a and 4b are illustrations of two preferred arrangements of current-carrying conductors contained within the slots of the elongated member, in accordance with the principles of the present invention; and
FIG. 5 is a perspective view of a completed transverse magnetic recording head in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring initially to FIGS. 1 and 1a, one embodiment of transverse magnetic printing head 10 comprises an elongated member 11 of magnetic material, such as ferrite and the like, fabricated into a comb-like shape having a plurality of teeth 12a–12z extending from one side thereof to form a plurality of slots 14a, . . . , 14m, 14n, . . . , each slot being bounded by a pair of adjacent teeth 12a. One of a like plurality of conductors 13 is placed in each slot 14. A support means 15 abuts the side surfaces of the elongated member from its bottom 11a to a line immediately below each of slots 14. Support means 15 is formed of a non-magnetic, insulative material such as an epoxy and the like. Depending upon the total length of elongated member 11, and the mechanical rigidity thereof to be maintained, an additional support means, such as a rod 16 may be utilized; the additional support member is shaped, as by formation of a recess 16a radially therein, to closely receive support means 15 and elongated member 11.

A sheet 18 of a material is magnetizable, in each of an array of small areas (e.g. 18m and 18n) thereon, in each of at least a pair of opposite magnetic directions. The sheet is caused to travel in a direction, indicated by arrow A out of the plane of the drawing, transverse to the direction defined by, and adjacent to the ends of, the elongated multiplicity of comb-teeth 12.

Each of the plurality of conductors 13a–13z, each extending through an associated one of slots 14a–14z, is driven by a separate current-driver means (not shown) to independently carry a flow of current therein in the same direction as the direction A of sheet travel (illustratively, out of the plane of the drawing). A flow of current of a selected magnitude and polarity through a conductor, e.g., 13m or 13n respectively, results in a magnetic field being generated. The field is concentrated by the magnetizable material of adjacent comb-teeth 12 to form a final magnetic field 19 of sufficient magnitude and direction (illustratively, counterclockwise) between the tips of adjacent teeth, e.g., magnetic field 19m formed between the ends of teeth 12m and 12n, and magnetic field 19n between teeth 12n and 12o, respectively, to magnetize the magnetizable material of an overlying region, e.g., 18m or 18n, respectively, of sheet 18 in a desired direction.

Referring now to FIG. 2, it is preferable, in order to reduce the number of current-driving means, that each slot house a group of conductors 25, with each group being of an independently driven conductor: a first set of current-carrying conductors, e.g., 25a, 25c, 25e, . . . , respectively positioned in sequential slots 14h, 14i, 14k, . . . , being completely independent from a second set of current-carrying conductors, e.g., 25b, 25d, 25f, . . . , respectively arranged in the same sequential set of slots 14a. Each set of conductors may consist of a single turn or a plurality of turns (as shown) in each slot.

By use of coincident-matrix techniques, the required magnetic field, e.g., magnetic field 27a for magnetizing sheet region 28a adjacent thereto, achieves a required field amplitude and direction directly when the individual magnetic fields, e.g., 29a and 29b, are generated in the same direction, e.g., counterclockwise, by flow of substantially equal currents in the proper direction, e.g., out of the plane of the drawing of FIG. 2, in each independent set of conductors, e.g., 25c and 25d, associated with the slot at which magnetic field 27a is to be formed.

Referring now to FIG. 3, elongated member 11 is preferably fabricated by laminating together a plurality of thin comb-like sheets 11b, 11c, . . . , 11n of a high permeability material. The individual sheets may be etched from a master sheet 30 of the desired material and may be stacked one upon the other with similarly ordered teeth 12 in alignment. Adhesive means 32, such as epoxy and the like, is advantageously spread upon the interior sheet surfaces to facilitate bonding of the laminations to each other. A tiny bead of the adhesive may be squeezed from between the overlying sheets, during lamination, to provide additional insulation between the elongated member and the insulated conductor 13 in each slot.

Returning to FIG. 1a, printing head 10 may be considered to be comprised of an array of a multiplicity of stacks N×M of recording heads, each head having an effective area across the gap of one of slots 14. The array is organized into N words of M digits each. Thus, an array of one thousand recording heads may be organized into 40 ( = N) words, each word having a total of 40 ( = M) digits. A word line 40 is independently wound through the M sequential slots of each of the N sequential words, while each of N digit lines 42 is independently and successively wound through a like ordered slot of each of the N word groups. We have found that a unidirectionally helical-wound word or digit line, e.g., consistently wound in the clockwise direction as shown in FIG. 1a, is normally unacceptable as each line acts with the unclosed magnetizable material of member 11 to produce undesirable magnetic effects in the regions at the end of at least each word-group of slots. This deleterious effect is overcome if the current in the conductor in alternating slots is flowing in opposite directions. Thus, a first word line 40 is sequentially wound in alternating directions through each of the first 40 slots 14, with a second, third, . . . , N-th word line being respectively wound in "zig-zag," i.e., alternating, directions through the sequential array of slots starting at, respectively, the 41st, 81st, 121st, . . . , 40(N–1)+1st slot and ending, respectively, at the 80th, 120th, . . . , 40N-th slot. A first digit line 42a is wound in alternating directions through the first slot of each word group, i.e., the 1st, 41st, 81st, 121st, . . . , 40(N–1)+1st slot 14 in such manner as to carry current, when driven, in the same direction as the direction of word line, which direction alternately reverses in slot-by-slot fashion, as hereinabove explained.

Similarly, the second digit line 42b is wound through the second slot of each word group, i.e., the 2nd, 42nd, 82nd, . . . , 40(N–1)+2nd slot of the array. Thus, a flow of half the total current required for magnetizing field formation may be caused in one word line 40 and one digit line 42 to generate the necessary orientation field only across the single slot wherein both the current-carrying lines are disposed. The pitch P between each slot centerline is chosen for the required "dot" spacing necessary for the size of the required indicia to be printed. It should be understood that, with uniform pitch P, the alternating-direction digit and word lines may be easily machine wound, as the wires are positioned straight through each slot 14 and do not require intricate bends or the like complex configurations in the region of the slots. The resulting small number of total lines are thus organized in a manner to be addressed by
coincident 2D matrix selection techniques, whereby
one current-driving means, of known type, is required
for each of M word lines and for each of N digit lines
for a total of 80(=N+M) current driving means.

Advantageously, each set of word or digit lines may
be selected by a driver-switch matrix, e.g., a 5×8 driv-
er-switch matrix being utilized to select the proper one
of each of the set of 40 digit or word lines, respectively,
by ripping through both sets of lines in accordance
with sequential clocking techniques. This approach
requires the least number of drivers, e.g., a total of 26,
but may require a clock rate as rapid as about 2.6 MHz.
for a printing speed of about 6000 lines (of up to 160
characters, at 10 characters per inch with a 16 inch long
printing head) per minute. The clock rate can be
reduced to about 65 KHz. by parallel data processing
within either the digit lines or the word lines, respec-
tively, are sequentially selected by the 5×8 driver-
switch matrix while all of the word lines or digit lines,
respectively, are simultaneously selected to respectiv-
ely cause simultaneous writing of one digit to each of the 40
word tracks across the array or, with simultaneous
selection of the digit lines, to cause one 40 digit word
block to be printed at the same instant. Either method
requires a total of 53 driving means, for the 1600 charac-
ter recording head organized with 40 word lines and 40
digit lines.

Referring now to FIG. 4a, a preferred embodiment of
a printing head having alternating-direction windings
in alternating slots, with independent winding of each of
the word and digit lines for matrix selection, utilizes a
pair of spaced-apart insulative members 50, each affi-
ced, as by adhesive means (not shown), to the curved
surface 16a of additional support member 16 and each
lying adjacent to an opposite side of elongated member
11. A plurality of conductive lead means 52 are fabri-
cated, as by printed circuit techniques and the like, upon
the outermost surface 50a of each insulator 50; each insula-
tive member supports a member of conductive
members 52 equal in number to the number of slots 14
between the totality of teeth 12. Each pair of aligned
lead means 52 is integrally joined by a short length 54 of
the lead means conductor attached theretbetween and
aligned with one of slots 14, to facilitate insertion of
each of the plurality of conductors 54 in the associated
one of the sequential slots of the elongated array. Thus,
a linear strip of insulative material is removed from a
sheet of such material after fabrication of lead means 52,
including lengths 54, to form spaced insulators 50 hav-
ing a slot therebetwixt for receiving teeth 12. The slot
is overlaid with the plurality of lengths 54 of the con-
ductor material. Thus, a first length, e.g., 54a, integrally
extends between a first pair of aligned conductor means,
e.g., 52a—52a, when the underlying insulative materials
is removed, to allow insertion in a first slot, e.g., 14a.

The next following conductor, e.g., 54a is formed by
the conductive material integrally extended between the
next following pair of aligned conductor means, e.g.,
52a—52a, for insertion in the next following slot,
e.g., 14a, while a subsequent conductor means, e.g.,
54a, extends between the associated aligned conductor
means e.g., 52a—52a, and so forth.

The conductor pattern fabricated on insulators
50—50 includes pattern portions 55 for alternately
connecting portions 54 in "zig-zag" manner to achieve
the required alternate-slot current-direction reversal,
I.e., the current flowing rightwardly in portion 54a
is caused to flow leftwardly in portion 54w; and so forth,
by placement of portions 55 therebetwixt. Means, such
as solder pads 56 and the like, may be provided for
connecting an external current-driver means to each
current-carrying conductor pattern 54 with a single pair
of connecting pads associated with each word or digit
line. It should be understood that a second set of insula-
tive means bearing other conductor means and their
integally extended conductor portions therebetwixt is
overlaid upon insulators 50—50 (bearing the word
lines) to provide the second group, e.g., the digit lines,
of matrix conductors in each slot.

Referring now to FIG. 4b, we have found that a
particularly advantageous embodiment, for use with
solid-state drivers, utilizes wound conductive-wire digit
and word lines, each having a plurality of conductor
turns positioned within each sequentially ordered slot
14 to reduce the required coincidence current by in-
creasing the number of field-generating turns per slot.
In the preferred embodiment, alternating slots receive
turns wound in opposite directions, i.e., a bifilar wound
coil, whereby both lines carry current in the same direc-
tion through each slot. The remaining (digit) line 62 is thus also wound
in opposite directions in each sequential pair of associated
slots, e.g., clockwise in slot 14k and reversed, as at 62a,
to be wound counterclockwise in the next slot receiving
that line. Thus, when one line carries current into the
plane of the drawing in alternating slots, e.g., dual con-
ductor turns 25a (FIG. 29 in slot 14d and dual conduc-
tor turns 25e in slot 14k, and carries a current flow out
of the plane of the drawing (towards the observer) in
the remaining slots, e.g., slots 14f and 14l, the remaining
conductor set must simultaneously carry current
into and out of the plane of the drawing in the same
direction, e.g., into the drawing plane as at conductor
sets 25b and 25f respectively in slots 14h and 14k
and out of the plane of the drawing as in conductor pairs 25d
and 25h in slots 14d and 14f. Thus, as previously men-
tioned, the magnetic field in, for example, slot 14f is
clockwise responsive to current flowing in each of
conductors 25c and 25d to each form a magnetic field
29c and 29d, respectively, of about half the required
magnitude of the total magnetizing field 27a. The in-
phase fields add to form field 27a of the required am-
plitude to magnetize a small region 58a of the overlying
media 20, to have a magnetic vector opposite to the
magnetic vector in an adjacent region 28a, responsive to
inward flow of current in conductors 25c and 25f in slot
14k, which establishes printing magnetic field 27b of
clockwise orientation in slot 14k.

Referring now to FIG. 5, a complete printing head
assembly 10 may advantageously utilize a light-weight,
substantially rigid backing member 70, formed of epoxy
and the like, to further support elongated magnetizable
member 11, and its insulative support member 15 and
additional support member 16. Backing member 70 is
shaped so as to permit curved members 71 to be
attached, as by fastening means 72, to provide a smooth