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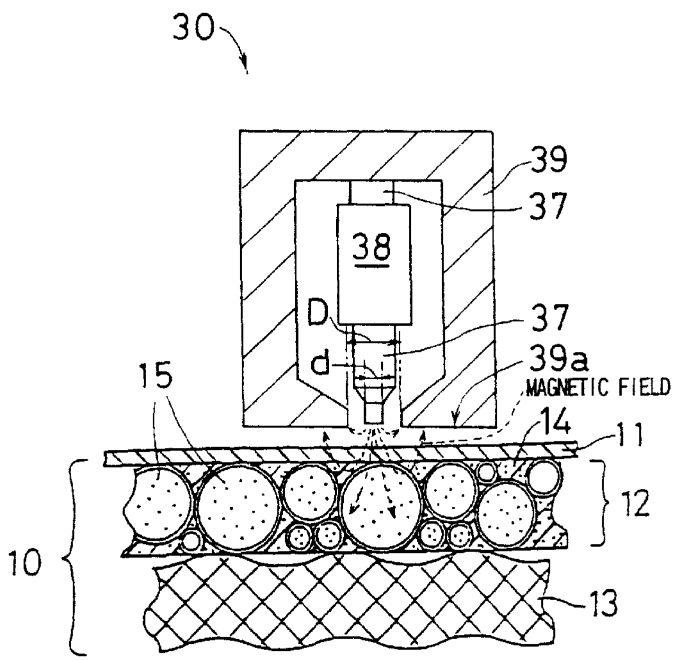
(54) Magnetic head for magnetic display and magnetic display

(57) A magnetic head (30) has a printing surface (39a) facing a magnetic display sheet (10), and comprises a yoke (39) in which a hole is formed in the printing surface (39a) thereof, a magnetic core (37), whose edge is inserted into the hole of the yoke (39) and which is magnetically connected to the yoke (39), for generating a dot-shaped recording field, an electromagnetic coil (38) for supplying a field to the magnetic core (37) based on a printing signal, and the like. Since the diameter d of the edge of the magnetic core is smaller than the diameter D of the holes, the difference between the diameter D and the diameter d is less than 0.9 mm, and the diameter D is 2.0 mm or less, the expansion of the foot slope in the distribution of the magnetic field can be eliminated. Thus the distribution of the recording magnetic field is optimized to realize a high quality magnetic print.

FIG.3



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Description

The present invention relates to a magnetic head for recording a still image on a magnetic medium and displaying an image based on printing information sent from an external host unit.

Hitherto, there has been known a magneto-sensitive magnetic display sheet as a display medium for developing/erasing colors in response to the direction and strength of a magnetic field (as disclosed in Japanese Unexamined Patent Publications JP-A 48-56393 (1973) and JP-A 2-146082 (1990) for example).

Because simple letters and graphics can be drawn on such a magnetic display sheet by touching the surface of the sheet with a magnetic pen containing a magnet and it can be used over and over again by erasing them, it has been put into practical use as a simple notepad.

Lately, an electronic information display apparatus records and displays a still image on a magnetic display sheet by a recording head generating a dot matrix magnetic field based on printing information sent from an external host unit is being developed. Because the electronic information display apparatus allows contents to be displayed to be arbitrarily changed by remote control from the external host unit, a great variety of information may be given and advertised widely to pedestrians when it is installed at public facilities, train stations, shops and the like. Further, because it requires no work in repapering posters and contributes in saving resources such as paper, it is considered to be promising as a future bulletin board.

In such electronic information display apparatus, a magnetic head is used to generate the dot matrix recording magnetic field based on printing signals (as disclosed in Japanese Unexamined Patent Publications JP-A 63-259678 (1988) and JP-A 7-281621 (1995) for example). The magnetic head is composed of a plurality of magnetic cores arranged in a row or in a plurality of rows for example, a plurality of electromagnetic coils mounted to each magnetic core, a yoke provided around each magnetic core with an air gap for leaking magnetism formed therebetween and others.

Semi-ringed lines of magnetic force are formed between an edge of the magnetic core and the yoke in such magnetic head, and the strength of the magnetic field is maximized at the position slightly separated in the radial direction from the extension of an axis of the magnetic core. Therefore, when the space between the edge of the magnetic core and the yoke is set longer than a certain extent, a printed dot whose circumference is vague is formed.

The printed dot is preferred to be a circular dot having a diameter slightly larger than a size of a pixel corresponding to a recording density and for that end, it is ideal for the recording magnetic field to have a columnar distribution. However, it is difficult in reality because the distribution of the magnetic field largely changes depending on the dimension of the magnetic core and the air gap.

It is hence an object of the present invention to optimize the distribution of the magnetic field generated by the magnetic core to provide a magnetic head for magnetic display and a magnetic display apparatus which can realize high quality magnetic printing.

Various aspects of the present invention are specified in the independant claims. Some preferred features of the independant claims are claimed in the dependant claims.

The invention provides a magnetic head for magnetic display comprising:

a yoke having a printing face which faces to a magnetic display medium and an air gap hole formed in the printing face;
a magnetic core whose edge is inserted into the air gap hole, for generating a dot-like recording magnetic field by magnetically coupling with the yoke; and
an electromagnetic coil for supplying a magnetic field to the magnetic core based on printing signals,
wherein a diameter d of the edge of the magnetic core is smaller than a diameter D of the air gap hole, a difference between the diameter D and the diameter d is less than 0.9 mm and the diameter D is 2.0 mm or less.

According to the present invention, since the diameter d of the edge of the magnetic core is smaller than the diameter D of the hole, the difference between the diameter D and the diameter d is less than 0.9 mm, and the diameter D is 2.0 mm or less, the expansion of the foot slope in the distribution of the magnetic field can be eliminated. As a result, the printed dots formed on the magnetic display medium become less blurred on the outline and have a high contrast.

In the present invention, it is preferable that the magnetic display medium to which the magnetic field from the magnetic head is applied is constructed so that micro-capsules containing magnetic powder and non-magnetic powder are distributed in plain and that the size of the micro-capsule is in a range from 10 μm to 1,000 μm.

According to the invention, since the clear printed dots can be obtained, high recording density and high quality magnetic printing may be realized.

The invention provides a magnetic display apparatus comprising a magnetic head for magnetic display; and a magnetic display medium which is writable and erasable by magnetism, the head comprising:

a yoke having a printing face which faces to the magnetic display medium and an air gap hole formed in the printing face;

a magnetic core whose edge is inserted into the air gap hole, for generating a dot-like recording magnetic field by magnetically coupling with the yoke; and

an electromagnetic coil for supplying a magnetic field to the magnetic core based on printing signals,

the edge of the magnetic core having a diameter d smaller than a diameter D of the air gap hole, a difference between the diameter D and the diameter d being less than 0.9 mm, the diameter D being 2.0 mm or less,

wherein a plurality of printed dots are formed to continuously overlap each other when writing a dot pattern on the magnetic display medium.

According to the invention, since the high contrast printed dots having less blur outline are continuously overlapped, high quality magnetic printing can be realized.

The invention provides a magnetic head for magnetic display comprising:

a yoke having a printing face which faces to a magnetic display medium and an air gap hole formed in the printing face;

a magnetic core whose edge is inserted into the air gap hole, for generating a dot-like recording magnetic field by magnetically coupling with the yoke; and

an electromagnetic coil for supplying a magnetic field to the magnetic core based on printing signals,

wherein in comparison between a rate of change in magnetic flux density and a rate of change in position from an outer peripheral end position of the edge of the magnetic core to an inner peripheral end position of a front portion of the air gap hole, a value of ratio of the change in flux density to the change in position in a vicinity of a reaction threshold value of the magnetic display medium is 1(T/mm) or more.

According to the invention, high contrast printed dots having less blur outline can be obtained with the result that high quality magnetic printing can be realized.

Other and further objects, features, and advantages of the invention will be more explicit from the following detailed description taken with reference to the drawings wherein:

Fig. 1 is a sectional view showing an electronic information display apparatus in which a magnetic head of the present invention is used;

Fig. 2 is a partial perspective view showing an internal structure of the electronic information display apparatus shown in Fig. 1:

Fig. 3 is a partial sectional view showing structures of a magnetic display sheet 10 and a magnetic head 30;

Figs. 4A through 4C, Figs. 5A through 5C, and Figs. 6A and 6B are graphs showing measured results of distribution of a magnetic field generated by a magnetic core 37;

Figs. 7 through 10 are an enlarged photograph showing a print sample on a magnetic display sheet; and

Fig. 11A through 11D are explanatory charts showing printing conditions which correspond to dots printed on the photographs.

Now referring to the drawings, preferred embodiments of the invention are described below.

Fig. 1 is a sectional view showing an electronic information display apparatus in which a magnetic head of the present invention is used and Fig. 2 is a partial perspective view thereof. A driven roller 50 is disposed within the upper part of a housing 1 and a driving roller 60 is disposed within the lower side thereof. A flexible endless magnetic display sheet 10 is spanned between the two rollers 50 and 60. The roller 50 is urged upward by an elastic member (not shown) such as a spring to give certain tension to the magnetic display sheet 10 to stably run the sheet and to maintain the flatness of the surface of the sheet. The roller 60 is rotationally driven by a motor 63 via gears 61 and 62. The magnetic display sheet 10 is circulated so as to move from the bottom to the top on the front side of the housing 1 (the left side in Fig. 1 or the back side in Fig. 2) and from the top to the bottom on the rear side of the housing 1 (the right side in Fig. 1 or the front side in Fig. 2) when the roller 60 is driven. A display window 2 made of a transparent material such as acrylic resin or glass is formed on the front of the housing 1.

A recording head 30 is provided at the lower part of the rear moving side of the magnetic display sheet 10 and generates a dot matrix type recording magnetic field toward the surface of the magnetic display sheet 10 based on printing signals sent from an external host unit (not shown). The recording head 30 has a plurality of electromagnetic coils disposed in stagger, for example, and is mounted on a carriage 31 which reciprocates in the direction of the width of the sheet. The carriage 31 is fixed to part of an endless belt 33 spanned between two pulleys 34 and 35 and is driven, while being guided by two guide shafts 32, by a motor 36 which rotationally drives the pulley 35.

An erasing head 20 is composed of a permanent magnet and the like having a length longer than the sheet width and is disposed so as to contact closely to the back of the magnetic display sheet 10 at the upper part of the front moving side of the magnetic display sheet 10.

Fig. 3 is a partial sectional view showing a structure of the magnetic display sheet 10 and the recording head 30. Coated and fixed around the whole surface of the magnetic display sheet 10 are micro-capsules 15 which develops colors in response to magnetism. Each micro-capsule 15 is composed of high viscous liquid and a spherical shell which encloses and holds the liquid. Dispersed within the liquid are magnetic particles which are nearly black and non-magnetic particles which are nearly white. For example, particle of black iron oxide (FeO) having a size of 0.1 to 5 μm is used as the magnetic particle and particle of white titanium oxide having a size of 0.1 to 5 μm is used as the non-magnetic particle. Further, as the high viscous liquid, organic solvent including aqueous solution, fat and oil and surface active agent type solvent is used and as the material of the shell, gelatin is mainly used. The size of the micro-capsule 15 is distributed within a range from 10 to 1,000 μm.

In case the particle size is less than 10 μm, the micro capsule 15 can include just a few magnetic particles and non-magnetic particles. When printing by attracting the nearly black magnetic particles to the surface of the sheet 10, the nearly white non-magnetic particles can be seen through the sheet because the amount of the magnetic particles is small. This causes an undesired result that low contrast gray dots are printed. When the particle size is more than 1,000 μm on the other hand, it becomes difficult to create an adequate printed dot because the particle size becomes close to a diameter d of an edge of a magnetic core 37 and a diameter D of a air gap hole in a recording head 39 and the number of micro-capsules 15 which represent one printed dot decreases. Further, it is not preferable that the recording head 39 as described later requires a large quantity of current because the larger the size of the micro-capsule 15, the longer the distance for moving the magnetic particles becomes. From these reasons, it can be said that the suitable size of the micro-capsule 15 is within the range from 10 to 1,000 μm.

The micro-capsule 15 is mixed with binder 14 made of highly transparent synthetic rubber type adhesive and the like and is coated to a base 11 made of a transparent material such as polyethylene terephthalate to form a capsule coating layer 12 of 40 to 1,000 μm thick, for example.

A protection sheet 13 made of polypropylene long-fibre unwoven cloth and the like is adhered on the back of the capsule coating layer 12 so as to be 30 to 1,000 μm thick, for example, to smoothly run the sheet.

Meanwhile, the recording head 30 comprises the box type yoke 39 made of a material of high magnetic permeability, the magnetic core 37 made of a material of high magnetic permeability uprightly provided within the yoke 39 and an electromagnetic coil 38 attached to the magnetic core 37. A plurality of magnetic cores 37 and electromagnetic coils 38 are provided corresponding to a plurality of printed dots. While the magnetic core 37 is formed into a columnar shape, the diameter of the edge thereof is smaller than that of the middle part and a tapered portion in which the diameter changes linearly is formed therebetween.

Numbers of circular air gap holes are formed on the printing face 39a of the yoke 39 and the edge of the magnetic core 37 is positioned at the center of each air gap hole. Leakage magnetic field is generated because there exist the air gap between the magnetic core 37 and the air gap hole. As shown in Fig. 3 as to the distribution of the magnetic field, semi-ringed lines of magnetic force are generated between the edge of the magnetic core 37 and the yoke 39 and the strength of the magnetic field is maximized at the position slightly separated in the radial direction from the extension of the axis of the magnetic core 37. Therefore, in the case where an interval between the magnetic core 37 and the yoke 39 exceeds a certain amount, dots with blurred peripheries are printed.

When the electromagnetic coil 38 is energized selectively corresponding to printing signals, a magnetic field is generated along the axial direction of the magnetic core 37. It passes through a magnetic circuit composed of the magnetic core 37, the air gap and the yoke 39 and generates a recording magnetic field from the air gap toward the magnetic display sheet 10. That is, the magnetic field generated by the electromagnetic coil 38 passes through the magnetic circuit composed of the magnetic core 37 (front end), the air gap, the edge of the yoke 39, the yoke 39 and the magnetic core 37 (rear end) and generates the magnetic field having a high magnetic flux density toward the surface of the sheet around the edge of the magnetic core 37 because there exists the air gap.

Next, the principle of the magnetic recording/displaying and erasure will be explained. When the recording head 30 approaches the surface of the magnetic display sheet 10 where the base 11 is positioned, and generates the recording magnetic field based on printing signals, the magnetic particles dispersed within the micro-capsule 15 are attracted to the side of the base 11 and due to the pressure, the non-magnetic particles move to the side of the protection sheet 13. Then, the part to which the recording magnetic field has been applied is observed as if it has developed nearly black color seeing from the surface side of the magnetic display sheet 10. That is, letters and symbols may be recorded by applying magnetic fields in dot matrix by using the recording head 30.

Next, when the erasing head 20 approaches the back of the magnetic display sheet 10, i.e. the side where the protection sheet 13 is positioned, the magnetic particles dispersed within the micro-capsule 15 are attracted to the side of the protection sheet 13 and due to the pressure, the non-magnetic particles move to the side of the base 11. Then, the part to which the erasing magnetic field has been applied turns nearly white seeing from the surface side of the magnetic display sheet 10. That is, the sheet may be erased uniformly by applying the erasing magnetic field across the whole surface of the sheet width.

Liquid having a predetermined viscosity is selected for the above-mentioned high viscous liquid within the micro-capsule 15 so as to hold the state of display caused by the magnetic particles moved to the back or the front side when the magnetic field has been applied. That is, it is selected to prevent the state of display from being collapsed which might otherwise occur when the particles moved once to the front or the back side settle or move due to vibration and the like when the viscosity of the liquid is low. Accordingly, the magnetic attracting force of the recording head 30 and the erasing head 20 must exceed the yield value of the above-mentioned liquid defined by the viscosity. Writing/erasure of the display is thus implemented.

Next, an operation of the whole apparatus will be explained. Making reference to Figs. 1 and 2, the magnetic display sheet 10 is circulated at a constant speed to erase the whole surface with the erasing head 20 before starting printing at first. Next, printing is carried out magnetically by receiving printing signals from the external host unit and feeding pulse current of several hundred microseconds to several tens miliseconds to the electromagnetic coil 38 while moving the recording head 30 in the direction of the sheet width every time when the development of image data of one printing line ends and applying the dot matrix magnetic fields to the surface of the magnetic display sheet 10.

When one line of printing is finished, the magnetic display sheet 10 is shifted by a predetermined feed pitch and is stopped to print based on image data developed for the next printing line. One sheet of image is then formed by repeating the development of the image data, the serial printing by the recording head 30 and the intermittent feed of the magnetic display sheet 10 as described above.

When a new image is to be printed, serial printing is carried out by the recording head 30 after erasing the whole face with the erasing head 20 by circulating the magnetic display sheet 10 at the constant speed in the same manner as described above.

Next, a result of changes of the printed dots studied by variously changing the diameter d of the edge of the magnetic core 37 and the diameter D of the air gap hole formed in the yoke 39 will be explained. Table 1 shows whether or not a blur is generated in the periphery of the printed dot formed on the magnetic display sheet 10. In Table 1, "O" represents those printed dots whose periphery is clear, " × " represents those printed dots whose periphery is blurred, and [-]represents impracticable settings

Table 1

Diameter d of edge portion of magnetic core 37 (mm)	Diameter D of hole (mm)				
	0.8	1.1	1.4	1.7	2.0
0.5	O	O	X	X	X
0.8	O	O	O	X	X
1.1	-	O	O	O	X
1.4	-	-	O	O	O
1.7	-	-	-	O	O
2.0	-	-	-	-	O

Accordingly, since the diameter d of the edge of the magnetic core 37 is smaller than the diameter D of the hole, the difference between the diameters D and d is less than 0.9 mm, and the diameter D is less than 2.0 mm, expansion at the foot of the magnetic field distribution can be eliminated. As a result, each printing dot formed in a magnetic display body is a clear and high-contrast printing dot in which there is little blurring of the contours can be attained. Also, although the printing dots exhibit ring-shaped density distribution in which the density in the center of the printing dot is low, this does not present a problem in practical applications.

Figs. 4A through 4C, Figs. 5A through 5C and Figs. 6A and 6B are graphs showing the measurement results of the distribution of the magnetic field generated by the magnetic core 37. The distribution of magnetic flux density is measured assuming that the capsule coating layer 12 of the magnetic display sheet 10 is positioned on a plane separated from the printing face 39a of the recording head 30 by a certain distance (ex. 50 μm) and by scanning a magnetic probe along this plane. The ordinate represents the flux density (unit T: tesla) and the abscissa represents position (mm) from the center of the magnetic core.

Fig. 4A shows a case when the diameter d of the edge of the magnetic core 37 is 0.5 mm and the diameter D of the air gap hole is 0.8 mm. It shows a "caldera volcano" type distribution in which the magnetic flux density is slightly dented around the center of the magnetic core, is maximized around the circumference of the edge of the magnetic core and drops sharply as the position is separated therefrom.

Although the reaction threshold value of the magnetic display sheet 10 differs depending on the diameters and amounts of the magnetic particles and the viscosity of the liquid within the micro-capsules 15, since the reaction threshold value of the magnetic display sheet 10 put to use is approximately 0.3T, in places where a flux density of 0.3T or more can be applied, the magnetic particles within the micro-capsules 15 are drawn toward the front surface of the magnetic display sheet 10 to impart a black coloring, and in places where only a flux density of less than 0.3T can be applied, the magnetic particles in the micro-capsules 15 do not react and the display remains white. Also, in the vicinity of the reaction threshold value (in the vicinity of approximately 0.3T in the case of the magnetic display sheet 10 used in this experiment) the magnetic particles slightly react and look gray. Where these gray colored portions in the vicinity of the reaction threshold value are numerous in the contoured portions of the printing dots, in other words where the flux density variation rate in the vicinity of the reaction threshold value of the contoured portions of the printing dots is low, the contours of the printing dots are blurred.

In the case where the diameter d of the edge portion is 0.5 mm and the diameter D of the hole 0.8 mm, the ratio of change in flux density in the vicinity of the reaction threshold value is calculated at a large ratio of change in flux density to position change of Ya/Xa = 2.2(T/mm), so that a clear printing dot without blurring of the contour can be attained at a diameter of approximately 0.8 mm.

Fig. 4B shows a case where the diameter d of the edge portion of the magnetic core 37 is 0.8 mm and the diameter D of the hole is 1.4 mm, the flux density exhibiting a distribution which is slightly dented in the vicinity of the center of the magnetic core, is maximum in proximity to the peripheral portion of the edge of the magnetic core, and abruptly decreases further away therefrom.

In the case where the diameter d of the edge portion is 0.8 mm and the diameter D of the hole 1.4 mm, the ratio of change in flux density in the vicinity of the reaction threshold value (approximately 0.3T) of the magnetic display sheet 10 put to use is calculated at a somewhat large value of Yb/Xb = 1.1(T/mm), so that a clear dot without blurring of the contour can be attained at a diameter of 1.3 mm.

Fig. 4C shows a case when the diameter d of the edge of the magnetic core 37 is 1.1 mm and the diameter D of the air gap hole is 1.4 mm. It shows a distribution in which the flux density is slightly dented in the vicinity of the center of the magnetic core, is maximized around the circumference of the edge of the magnetic core and drops abruptly as the position is separated therefrom.

In the case where the diameter d of the edge portion is 1.1 mm and the diameter D of the hole 1.4 mm , the ratio of change in flux density in the vicinity of the reaction threshold value (approximately 0.3T) is calculated at a large ratio of change in flux density to position change of Yc/Xc = 2.4(T/mm), so that a clear printing dot without blurring of the contour can be attained at a diameter of approximately 1.4 mm. Also, even in the case of printing wherein the central density of the printing dot exhibits a somewhat concave ring-shaped density distribution and the central portion is blurred, by printing with the dots overlapping each other favorable printing results can be attained. In addition, where letters and diagrams are normally printed, essentially favorable printing can be attained by overlapping a plurality of dots.

Fig. 5A shows a case when the diameter d of the edge of the magnetic core 37 is 1.1 mm and the diameter D of the air gap hole is 1.7 mm. It shows a distribution in which the flux density is dented in the vicinity of the center of the magnetic core, is maximized around the circumference of the edge of the magnetic core and drops abruptly as the position is separated therefrom.

In the case where the diameter d of the edge portion is 1.1 mm and the diameter D of the hole 1.7 mm, the ratio of change in flux density in the vicinity of the reaction threshold value (approximately 0.3T) is calculated at a large ratio of change in flux density to position change of Yd/Xd = 1.0(T/mm), so that a clear printing dot without blurring of the contour can be attained at a diameter of approximately 1.4 mm. Also, even in the case of printing wherein the central density of the printing dot exhibits a somewhat concave ring-shaped density distribution and the central portion is blurred, by printing with the dots overlapping each other favorable printing results can be attained.

Fig. 5B shows a case when the diameter d of the edge of the magnetic core 37 is 1.7 mm and the diameter D of the air gap hole is 2.0 mm. It shows a distribution in which the flux density is largely dented in the vicinity of the center of the magnetic core, is maximized around the circumference of the edge of the magnetic core and drops abruptly as the position is separated therefrom.

In the case where the diameter d of the edge portion is 1.7 mm and the diameter D of the hole 2.0 mm, the ratio of change in flux density in the neighborhood of the reaction threshold value (approximately 0.3T) of the magnetic display sheet 10 put to use is calculated at a large value of Ye/Xe = 2.2 (T/mm) and a clear printing dot without blurring of the contour can be attained at a diameter of 2.0 mm. Also, even in the case of printing wherein the central density of the printing dot exhibits a somewhat concave ring-shaped density distribution and the central portion is blurred, by printing with the dots overlapping each other, favorable printing results can be attained.

Fig. 5C shows a case where the diameter d of the edge portion of the magnetic core 37 is 1.4 mm and the diameter D of the hole is 2.0 mm, the flux density exhibiting a distribution which is slightly dented in the vicinity of the center of the magnetic core, is maximum in proximity to the peripheral portion of the edge of the magnetic core, and abruptly decreases further away therefrom.

In the case where the diameter d of the edge portion is 1.4m and the diameter D of the hole 2.0 mm, the ratio of change in flux density in the neighborhood of the reaction threshold value (approximately 0.3T) of the magnetic display sheet 10 put to use is calculated at a large value of Yf/Xf = 2.3 (T/mm) and a clear printing dot without blurring of the contour can be attained at a diameter of 2.0 mm. Also, even in the case of printing wherein the central density of the printing dot exhibits a somewhat concave ring-shaped density distribution and the central portion is blurred, by printing with the dots overlapping each other, favorable printing results can be attained.

Fig. 6A shows a case where the diameter d of the edge portion of the magnetic core 37 is 0.5 mm and the diameter D of the hole is 1.4 mm, the flux density exhibiting the "caldera volcano"-type distribution which is slightly dented in the vicinity of the center of the magnetic core, is maximum in proximity to the peripheral portion of the edge of the magnetic core, and gradually decreases further away therefrom.

In the case where the diameter d of the edge portion is 0.5 mm and the diameter D of the hole 1.4 mm, the rate of change in flux density in the neighborhood of the reaction threshold value (approximately 0.3T) of the magnetic display sheet 10 put to use is calculated at a small value of Yg/Xg = 0.53(T/mm), a printing dot having a blurred contour is produced at a diameter of 1.0 mm.

Fig. 6B shows a case where the diameter d of the edge portion of the magnetic core 37 is 0.8 mm and the diameter D of the hole is 1.7 mm, the flux density exhibiting a distribution which is slightly dented in the vicinity of the center of the magnetic core, is maximum in proximity to the peripheral portion of the edge of the magnetic core, and gradually decreases further away therefrom.

In the case where the diameter d of the edge portion is 0.8 mm and the diameter D of the hole 1.7 mm, the rate of change in flux density in the neighborhood of the reaction threshold value (approximately 0.3T) of the magnetic display sheet 10 put to use is calculated at a small value of Yh/Xh = 0.5(T/mm), a printing dot having a blurred contour is produced at a diameter of 1.3 mm.

As seen from these measurement results, in order to realize a print with little blurred contours, it is preferable to set the diameter d of the edge portion and the diameter D so that the ratio of change in flux density is $Y/X \geqq 1$.

It can be also seen that although the absolute value of the distribution itself of the magnetic fluxes shown in Figs. 4 to 6 may change, the tendency of the distribution is not changed so much even when the quantity of current to be fed to the electromagnetic coil 38 in the recording head 39 is changed more or less. Accordingly, it is possible to optimize the shape of the printed dot by controlling the quantity of current to be fed and the feed time corresponding to the sensitivity of the magnetic display sheet 10. It can be seen from these facts that it is important to set the diameter d of the edge of the magnetic core 37 and the diameter D of the air gap hole at adequate size in advance.

Next, experiments on evaluation of print will be explained. Figs. 7 through 10 are enlarged photographs showing samples of prints magnetically printed on the magnetic display sheet by changing the diameter d of the edge of the magnetic core 37 and the diameter D of the air gap hole variously. Figs. 11A through 11D are explanatory charts showing printing conditions corresponding to the printed dots on the photographs.

Fig. 7 is a printing sample in which the diameter D of the hole is 1.1 mm and the diameter d of the magnetic core edge portion is 1.1 mm, and the right side is a printing sample where the dots overlap each other at a printing pitch of 0.7 mm. In the enlarged photograph, in contrast to the micro-capsules of the magnetic display sheet 10 being observed in particle shape, there is little blurring of the contours and a favorable printing result is achieved.

Fig. 8 is a printing sample in which the diameter D of the hole is 1.4 mm and the diameter d of the magnetic core edge portion is 1.4 mm (upper sample) and 1.1 mm (lower sample), and the right side is a printing sample where the dots overlap each other at a printing pitch of 0.9 mm. Also in this photograph, there is little blurring of the contours and a favorable printing result is achieved.

Fig. 9 is a printing sample in which the diameter D of the hole is 1.7 mm and the diameter d of the magnetic core edge portion is 1.7 mm (upper), 1.4 mm (middle) and 1.1 mm (lower), and the right side is a printing sample where the dots overlap each other at a printing pitch of 1.1 mm. Also in this photograph, there is little blurring of the contours and a favorable printing result is achieved.

Fig. 10 is a printing sample in which the diameter D of the hole is 2.0 mm and the diameter d of the magnetic core edge portion is 2.0 mm (upper), 1.7 mm (middle) and 1.4 mm (lower), and the right side is a printing sample where the dots overlap each other at a printing pitch of 1.3 mm. Also in this photograph, there is little blurring of the contours and a favorable printing result is achieved.

Here the printing pitch, where forming letters or diagrams, is able to be modified within a range from a value larger than a formed dot/2 and less than a formed dot/1.414213 ··· (root 2), and in particular a printing pitch calculated from the formed dot/1.414213 ··· (root 2) is suitable. Although Figs. 7 through 10 were printed at the printing pitch calculated by formed dot/1.414213 ··· (root2), even in cases where the central density of the printing dot exhibits a concave ring-shaped density distribution as shown in Fig. 9 and Fig. 10, a favorable printing result can be achieved by printing with the dots overlapping each other. Also, where letters and diagrams are normally printed, because printing is performed by overlapping a plurality of dots, essentially favorable printing is attained.

In addition, with regard to the size of the dots, as well as the number of dots forming one screen image decreasing where the size is too large, in case where the printing dot has a central density which exhibits a concave ring-shaped density distribution, printing must be performed by adjusting the printing pitch more finely and overlapping the dots, therefore there is a possibility that this may cause a reduction in the printing speed, therefore to perform printing at an optimum printing pitch, the upper limit is thought to be where the diameter D of the hole is approximately 2.0 mm.

Once the printing dot increases in the above manner, although the central density has a tendency to exhibit a concave ring-shaped density distribution, by adjusting the printing pitch and performing printing by overlapping each dot slightly, the concavity in the central density can be reduced.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description and all changes which come within the meaning and the range of equivalency of the claims are therefore intended to be embraced therein.

Claims

1. A magnetic head (30) for magnetic display comprising:

a yoke (39) having a printing face (39a) which faces to a magnetic display medium (10) and an air gap hole formed in the printing face;
a magnetic core (37) whose tip is inserted into the air gap hole, for generating a dot-like recording magnetic field by magnetically coupling with the yoke; and
an electromagnetic coil (38) for supplying a magnetic field to the magnetic core based on printing signals,
wherein a diameter d of the tip of the magnetic core is smaller than a diameter D of the air gap hole, a difference between the diameter D and the diameter d is less than 0.9mm and the diameter D is 2.0 mm or less.

2. A magnetic head for magnetic display as claimed in claim 1, wherein the magnetic display medium (10) to which the magnetic field from the magnetic head is applied comprises micro-capsules (15) containing magnetic powder and non-magnetic powder, the size of the micro-capsule being in a range from 10 μm to 1,000 μm.

3. A magnetic head as claimed in claim 2, wherein said range is from 10 μm to 200 μm, or 200 μm to 400 μm or 400 μm to 600 μm or 600 μm to 800 μm or 800 μm to 1000 μm.

4. A magnetic display apparatus comprising a magnetic head (30) for magnetic display; and a magnetic display medium (10) which is writable and erasable by magnetism,

the head comprising:
a yoke (39) having a printing face (39a) which faces to the magnetic display medium (10) and an air gap hole formed in the printing face;
a magnetic core (37) whose tip is inserted into the air gap hole, for generating a dot-like recording magnetic field by magnetically coupling with the yoke; and
an electromagnetic coil (38) for supplying a magnetic field to the magnetic core based on printing signals,
the edge of the magnetic core having a diameter d smaller than a diameter D of the air gap hole, a difference between the diameter D and the diameter d being less than 0.9 mm, the diameter D being 2.0 mm or less,
wherein a plurality of printed dots are formed to continuously overlap each other when writing a dot pattern on the magnetic display medium.

5. A magnetic display apparatus as claimed in claim 4, wherein the magnetic display medium comprises microcapsules (15) containing magnetic powder and non-magnetic powder, the size of the microcapsules being in the range from 10 μm to 1.000 μm.

6. A magnetic display apparatus as claimed in claim 5, wherein the range is from 10 μm to 200 μm, or 200 μm to 400 μm, or 400 μm to 600 μm, or 600 μm to 800 μm, or 800 μm to 1000 μm.

7. A magnetic head (30) for magnetic display comprising:

a yoke (39) having a printing face (39a) which faces to a magnetic display medium and an air gap hole formed

in the printing face;
a magnetic core (37) whose tip is inserted into the air gap hole, for generating a dot-like recording magnetic field by magnetically coupling with the yoke;
and an electromagnetic coil (38) for supplying a magnetic field to the magnetic core based on printing signals, wherein in comparison between a rate of change in magnetic flux density and a rate of change in position from an outer peripheral end position of the tip of the magnetic core to an inner peripheral end position of a front portion of the air gap hole, a value of ratio of the change in flux density to the change in position in a vicinity of a reaction threshold value of the magnetic display medium is 1(T/mm) or more.

FIG.1

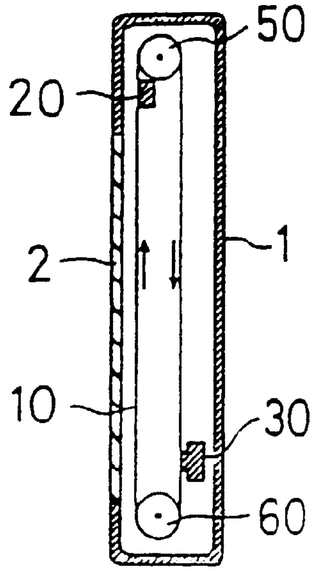


FIG.2

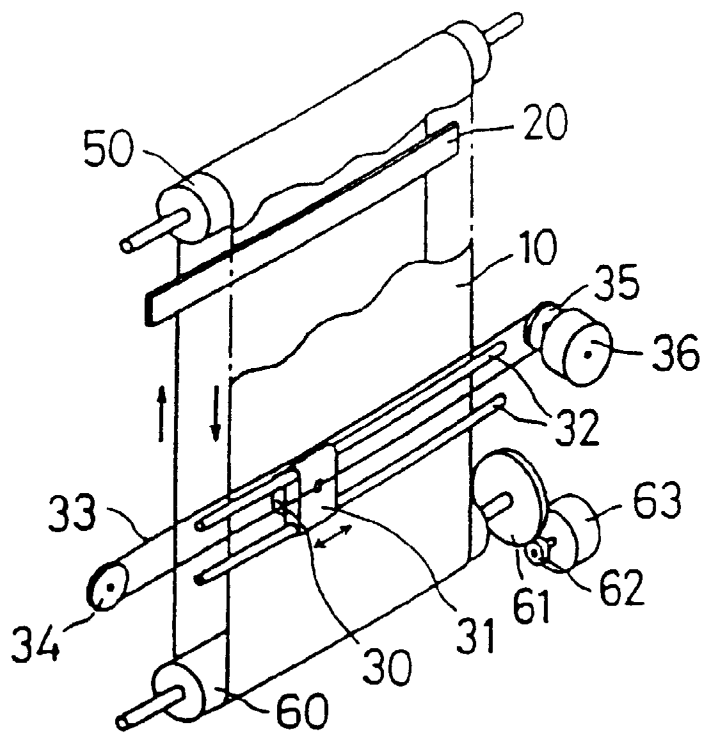


FIG. 3

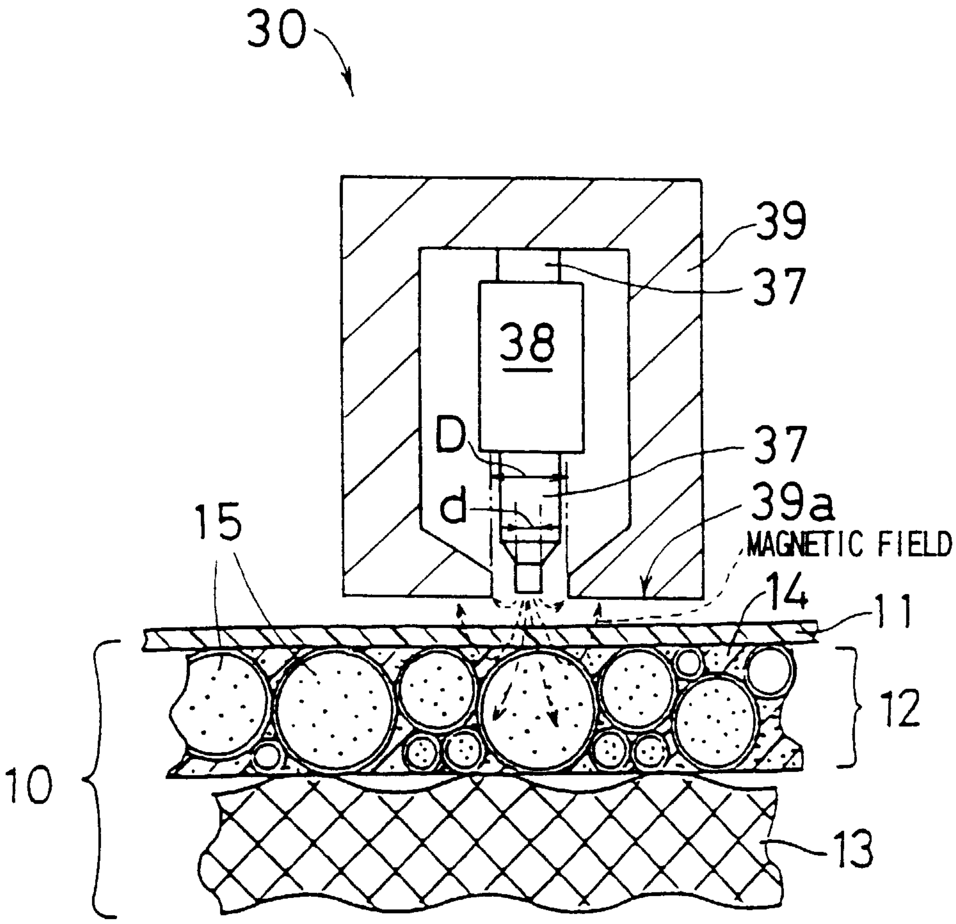


FIG.4A

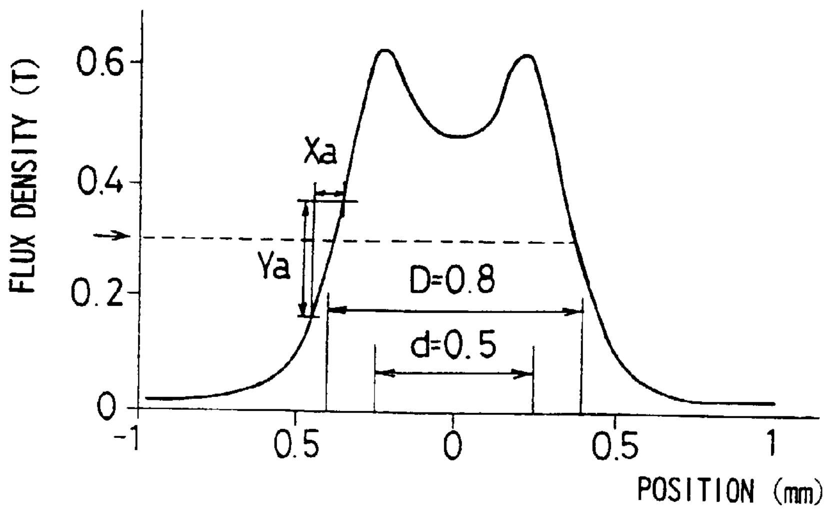


FIG.4B

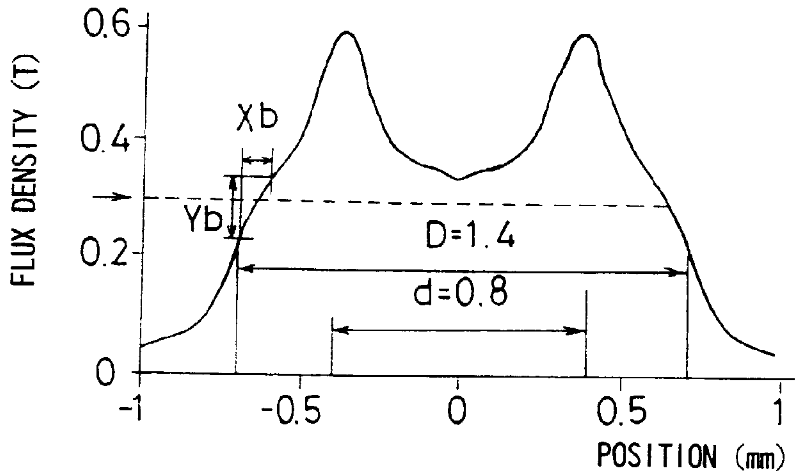


FIG.4C

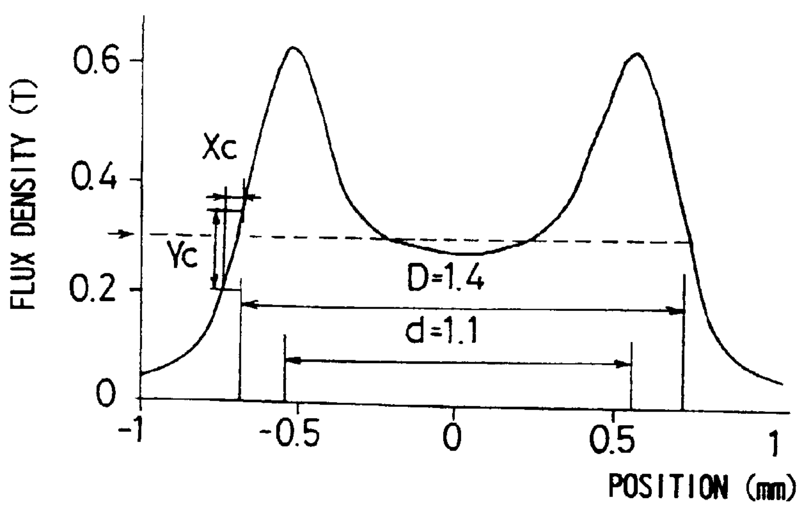


FIG.5A

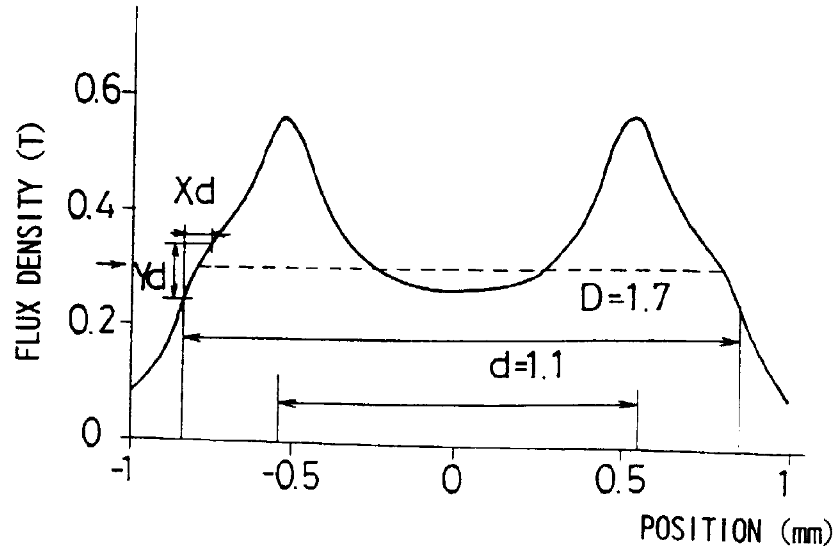


FIG.5B

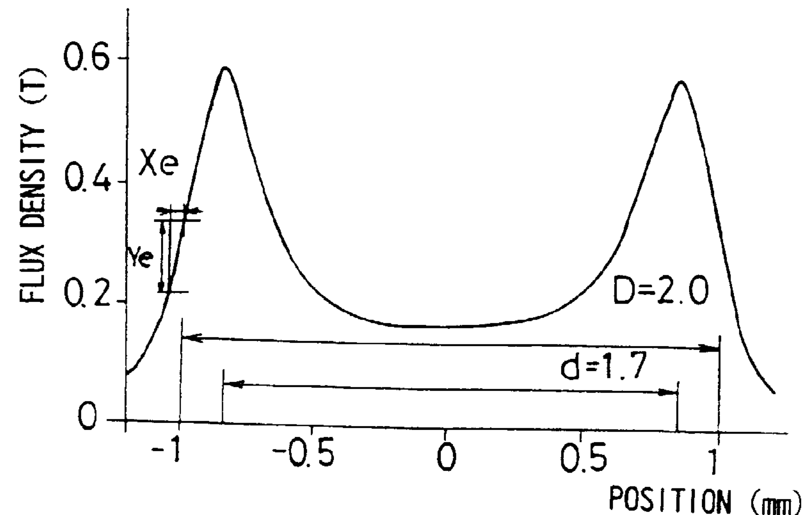


FIG.5C

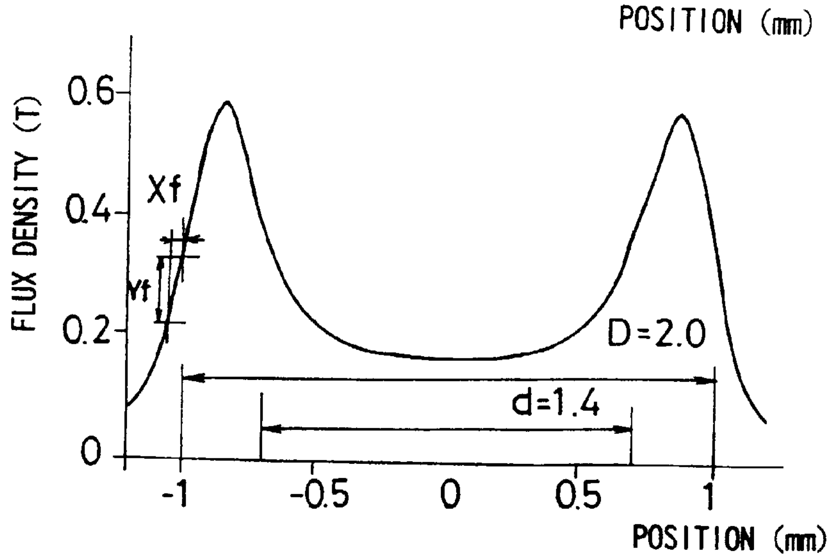
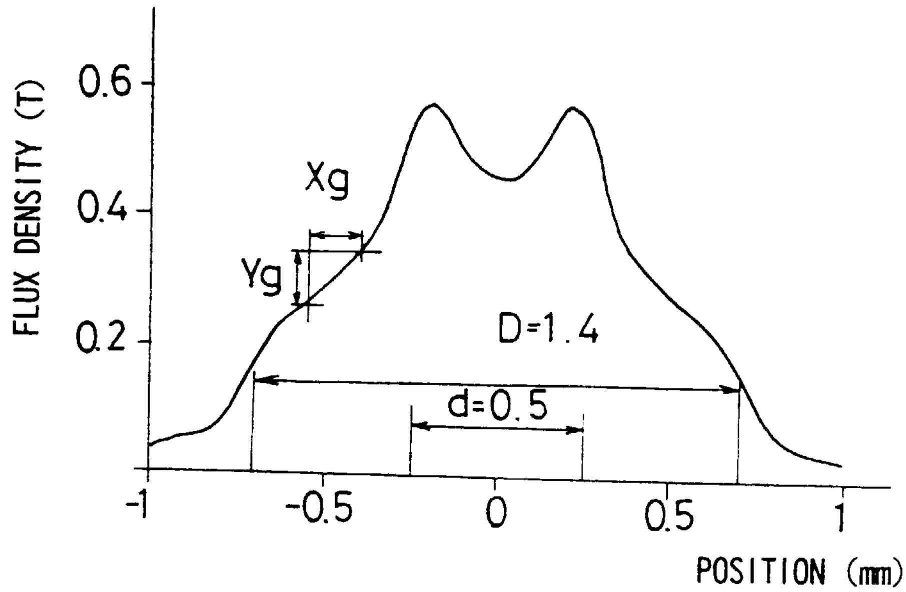
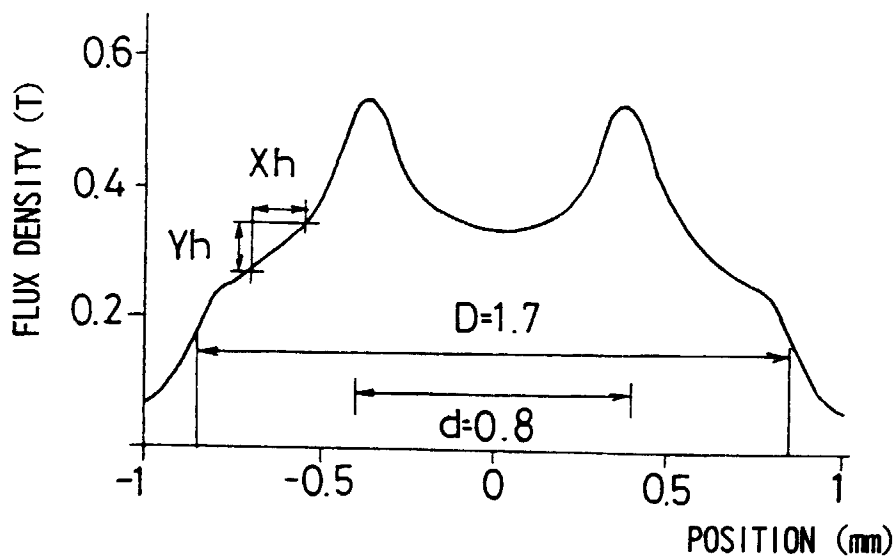


FIG.6A



FLUX DENSITY (T)
0.6
0.4
0.2
Xg
Yg
D=1.4
d=0.5
-1
-0.5
0
0.5
1
POSITION (mm)

FIG.6B



FLUX DENSITY (T)
0.6
0.4
0.2
Xh
Yh
D=1.7
d=0.8
-1
-0.5
0
0.5
1
POSITION (mm)

FIG. 7

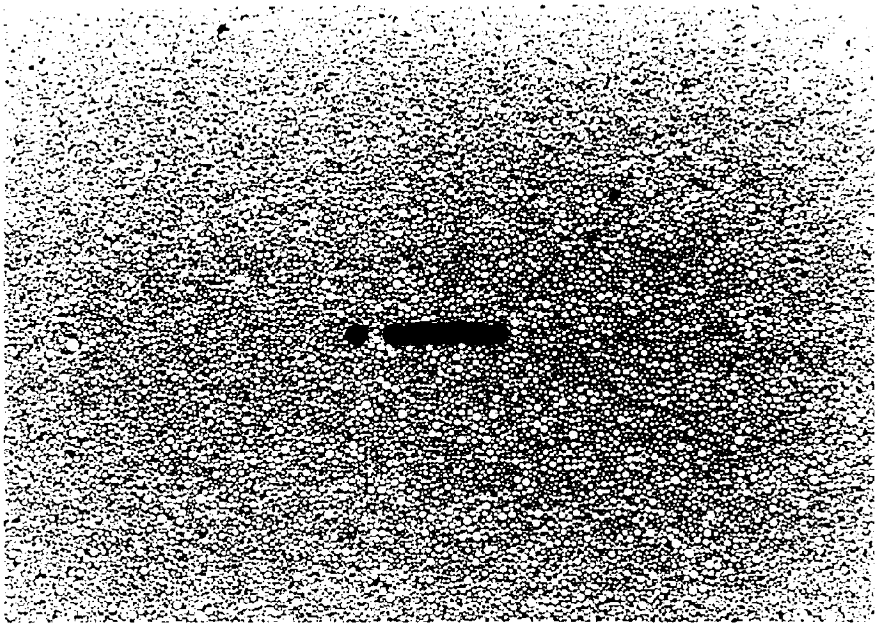


FIG. 8

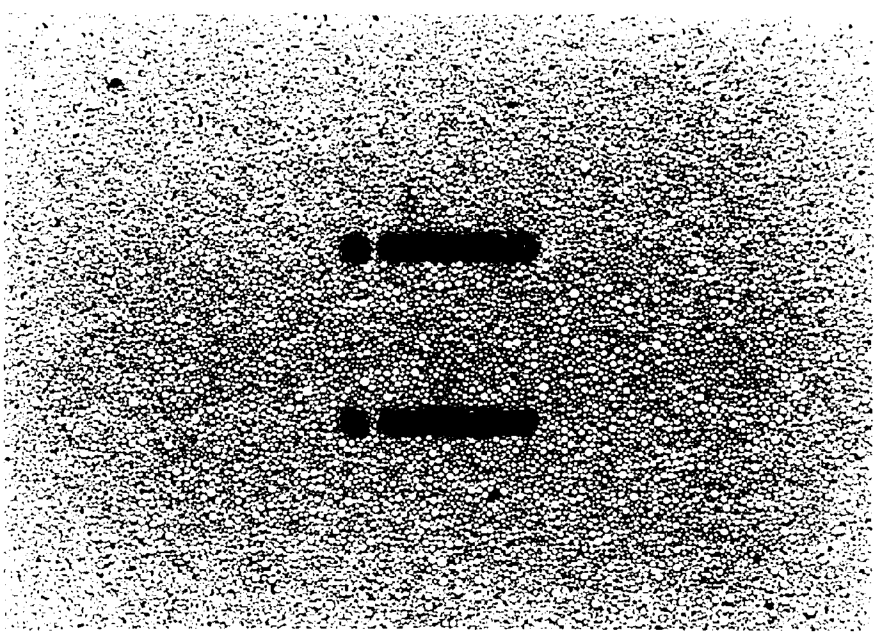


FIG.9

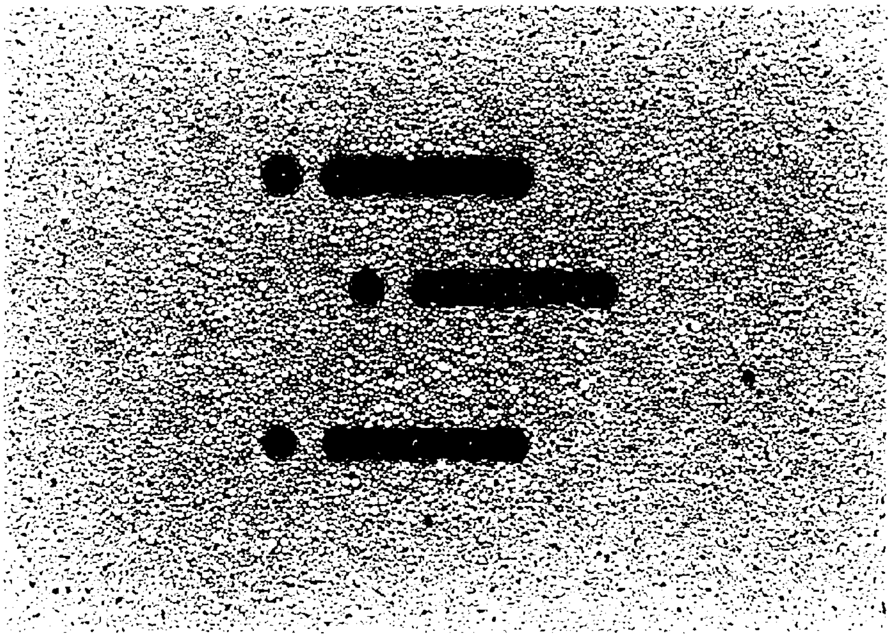


FIG.10

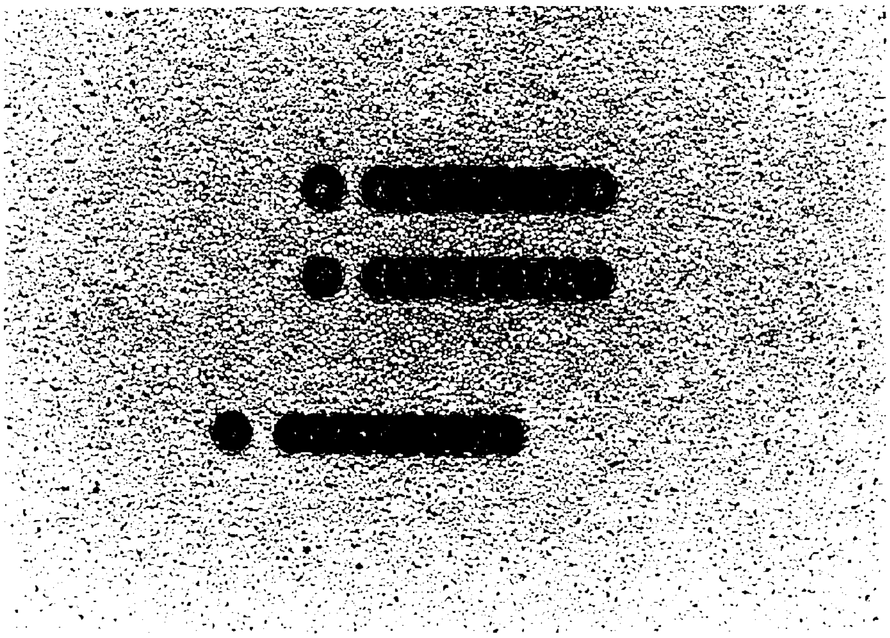


FIG.11A

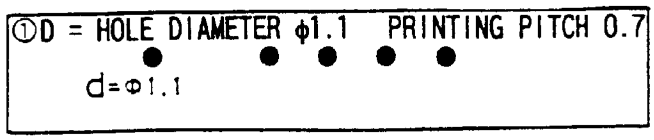


FIG.11B

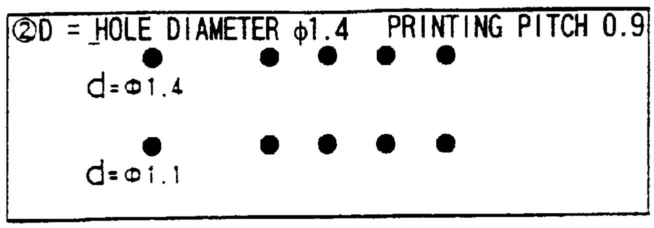


FIG.11C

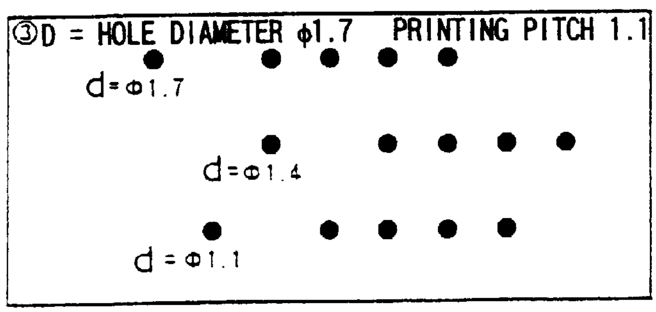


FIG.11D