MAGNETIC PARTICLE PATTERN IN RADIATING FORM NEAR CORNERS OF A KEYSLOT ON WORKPIECE SURFACE

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Abstract: The objective of this study was an explanation of the reason causing the magnetic particle pattern in radiating form near corners of a keyslot on workpiece surface in theory.
An item analysis was conducted on the distribution of magnetic charges along the convex edges of a discontinuity on the ferromagnetic workpiece surface at magnetization and the magnetic force acting upon a magnetic particle near the corners.
The principle finding of the item analysis was that around a large square hole, a parallelogram slot and near corners of a keyslot on the workpiece surface there sometimes will appear magnetic particle pattern in radiating long straight lines starting from the corners of them and spreading out along the 45°lines.
On the basis of these findings the deduction mentioned above was verified not only by a magnetic particle testing experiment made in the summer of 1995 by the author etc, but also by some experiences of magnetic particle inspection in production.

Reference[1] successfully explained quantitatively the reason causing the strange magnetic particle pattern around a small square hole (0.6×0.6mm) on the workpiece surface—four long straight lines starting from the four corners of the square hole. Some of the readers asked:"Will this radiating type of magnetic particle pattern also appear around a large square hole on the workpiece surface?" In order to answer this question the author analyzes again as following.

1. Magnetic charges distribution along the edges of a rectangular hole on the workpiece surface

On the basis of the traditional concept[1-4], in longitudinal magnetization the distribution of magnetic charges along the edges of a rectangular hole on the workpiece surface is shown in Figure 1.a. But from the concept of magnetic dipole chains[5~7], it can be derived that the distribution of magnetic charges along the convex edges of a rectangular hole on the workpiece surface also has the probability, which is shown in Figure 1.b.

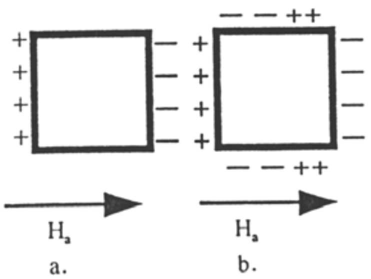


Figure 1 **along** **th**

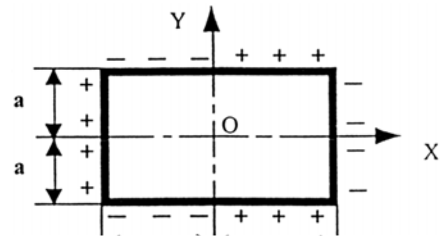


Figure 2 Dimensions and coordinates of a rectangular hole

H_a

2. Magnetic leakage field yielded by a rectangular hole

The dimensions of the rectangular hole (2a×2b) and the coordinates(XOY)are shown as Figure 2. The components of magnetic field yielded by the hole at arbitrary point P(x ,y) on the workpiece surface are H_x and H_y:

$$H_x=H_{1x}+H_{2x} \quad (1)$$

$$H_y=H_{1y}+H_{2y} \quad (2)$$

In which, H_1 is the magnetic field caused by the magnetic charges along the two Y direction edges of the rectangular hole.

H_2 is the magnetic field caused by the magnetic charges along the two X direction edges of the rectangular hole.

From references [8,9] it can be known that

(3)

(4)

$$H_{1x}=\frac{\sigma_l}{4\pi\mu_o}\left\{\frac{1}{x-b}\left[\frac{y-a}{\sqrt{(x-b)^2+(y-a)^2}}-\frac{y+a}{\sqrt{(x-b)^2+(y+a)^2}}\right]+\frac{1}{x+b}\left[-\frac{y-a}{\sqrt{(x+b)^2+(y-a)^2}}+\frac{y+a}{\sqrt{(x+b)^2+(y+a)^2}}\right]\right\}$$

$$H_{1y}=\frac{\sigma_l}{4\pi\mu_o}\left[-\frac{1}{\sqrt{(x-b)^2+(y-a)^2}}+\frac{1}{\sqrt{(x-b)^2+(y+a)^2}}+\frac{1}{\sqrt{(x+b)^2+(y-a)^2}}-\frac{1}{\sqrt{(x+b)^2+(y+a)^2}}\right]$$

$$H_{2x}=\frac{\sigma_l}{4\pi\mu_o}\left[\frac{1}{\sqrt{(x-b)^2+(y-a)^2}}-\frac{1}{\sqrt{(x+b)^2+(y-a)^2}}+\frac{1}{\sqrt{(x-b)^2+(y+a)^2}}-\frac{1}{\sqrt{(x+b)^2+(y+a)^2}}\right]$$

$$H_{2y}=\frac{\sigma_l}{4\pi\mu_o}\left\{\frac{1}{y-a}\left[-\frac{x-b}{\sqrt{(x-b)^2+(y-a)^2}}+\frac{x+b}{\sqrt{(x+b)^2+(y-a)^2}}\right]+\frac{1}{y+a}\left[-\frac{x-b}{\sqrt{(x-b)^2+(y+a)^2}}+\frac{x+b}{\sqrt{(x+b)^2+(y+a)^2}}\right]\right\}$$

here, σ_l is the magnetic charge density over the edges (Wb/m).

μ_o is the magnetic permeability for vacuum, and $\mu_o = 4\pi\times10^{-7}$ H/m.

3. Magnetic particle pattern at the four corners of a rectangular hole

From expressions (1)~(6) every component of the magnetic field strength at the four corners of a rectangular hole can be found, they all approach to infinite, but point at different directions. And the directions of H_1 and H_2 are just opposite, so the effects of the two offset each other. Hence, in the case of Figure 1.b. there is never special magnetic particle pattern at the four corners of a rectangular hole.

The positive and negative linear magnetic charges along the X direction edges of the rectangular hole in Figure 2 are formed from the broken magnetic dipole chains [5] under and near the convex edges of the hole [6, 7]. And a fixed condition must be satisfied, which depends on multiple factors as the shape and size of the sample and the hole, the magnetic characters of the material and the magnetized degree etc, so only in the case, when the condition mentioned above is satisfied, positive and negative linear magnetic charges will appear along the convex edges of a rectangular hole on the workpiece surface parallel with the magnetizing field, as show in Figure 1.b. In ordinary circumstances the result of magnetization is still described by the traditional concept (Figure 1. a).

From expressions (3) and (4), H_{1x} and H_{1y} at the four corners of a rectangular hole can be calculated out as shown in Figure 3. a. On the basis of reference [1], at this time the four corners of a rectangular slot on the workpiece surface must adsorb magnetic particles to form"abnormal" magnetic particle pattern along 45°straight lines (Figure 3.b), and this is not relevant to the length and width of the slot (a, b). That is, the dimensions of a rectangular hole are not the reason causing this"abnormal" magnetic particle pattern.

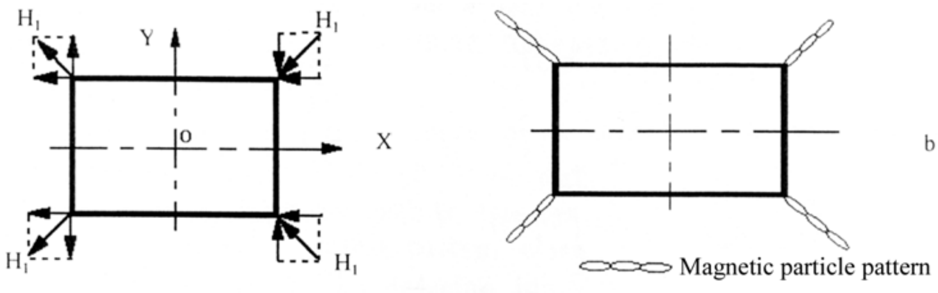


Figure 3 Magnetic field strength and "abnormal" magnetic particle pattern at the four corners of a rectangular hole on the workpiece surface

The square hole is a special case of the rectangular holes (b=a), naturally the magnetic particle pattern around its four corners must spread out along the two extension lines of its diagonals. And this was verified by the experiment carried out in the summer of 1995[1].

4. Magnetic field caused by a parallelogram hole and magnetic particle pattern around its four corners

The dimensions of a parallelogram hole (a, b, c) and the coordinates are shown as Figure 4.a. If there is no linear magnetic charges along the convex edges of the hole near the magnetizing field, the components of the magnetic

(7)

leakage field yielded by the parallelogram hole are H_{3x} and H_{3y}:

$$H_{3x}=\frac{\sigma_t}{4\pi\mu_0}\{\frac{1}{x-b}\left[\frac{y-a}{\sqrt{(x-b)^2+(y-a)^2}}-\frac{y+a}{\sqrt{(x-b)^2+(y+a)^2}}\right]+\frac{1}{x+b}\left[-\frac{y-a+c}{\sqrt{(x+b)^2+(y-a+c)^2}}+\frac{y+a+c}{\sqrt{(x+b)^2+(y+a+c)^2}}\right]$$

$$H_{3y}=\frac{\sigma_t}{4\pi\mu_0}\left[-\frac{1}{\sqrt{(x-b)^2+(y-a)^2}}+\frac{1}{\sqrt{(x-b)^2+(y+a)^2}}+\frac{1}{\sqrt{(x+b)^2+(y-a+c)^2}}-\frac{1}{\sqrt{(x+b)^2+(y+a+c)^2}}\right]$$

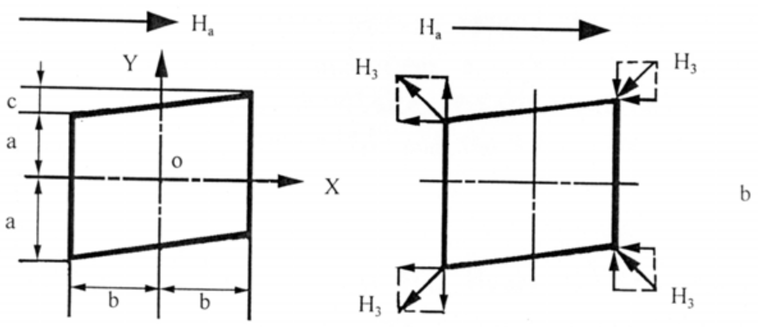
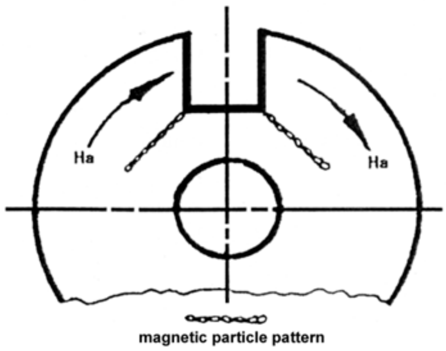


Figure 4 Dimensions and coordinates of a parallelogram hole and magnetic field strength at its four corners

From expressions (7) and (8), the components of magnetic field strength at the four corners of the parallelogram hole can be calculated out, they all approach to infinite, so around the slot also appears magnetic particle pattern in long straight lines presenting an angle of 45°with the magnetizing field (Figure 4. b). This was also verified by experiment, because afterwards the accurate measurement for the small hole on the sample of the experiment in 1995 discovered that at the two sides of the small square hole designed originally, there appears a deviation of 13°due to the reason of machining.

5. Magnetic particle pattern nea the corners of a keyslot on the work piece surface

On the basis of the same reason it can be proved that near the corners of a keyslot there will be appearing this type of "abnormal" magnetic particle pattern along the 45ºstraight lines(Figure 5). This deduction has already been verified by some experiences of magnetic particle inspection in production.



cle pattern near the corners of a keyslot

6. Conclusion

6.1 When the work piece is magnetized, an equally distributed linear magnetic charges will appear along the convex edges of an opening hole, parallel with the magnetizing field, due to the breaking of the magnetic dipole chains beneath those edges.

6.2 If uniformly distributing linear magnetic charges arise along the convex edges of a rectangular opening hole, parallel to the magnetizing field, the form of the magnetic particle pattern over the hole is similar to the hole itself.

6.3 If there are no uniformly distributing magnetic charges along the convex edges of a rectangular opening hole, parallel to the magnetizing field, an "abnormal" magnetic particle pattern will appear, spreading out from the four corners of the hole, along the 45°straight lines.

6.4 Around the corners of a parallelogram hole and near a keyslot there will appear the magnetic particle pattern spreading out along 45°straight lines in a fixed condition. This has already been verified by production experiences.

6.5 The "abnormal" magnetic particle pattern around the four corners of a rectangular hole or a parallelogram hole and near a keyslot, spreading out along 45°straight lines are all the normal inevitable result expected by the theory of linear magnetic dipole with finite length[8,9] and the conception of magnetic dipole chains [5~7].

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