Advantages of Stepped Core over Square Core

Introduction

- The cross section of the transformer core may be rectangular, square or stepped.
- Generally the circular coils are preferred for distribution transformer whereas the square and stepped cores are preferred for power transformer.

- The cross section of the core may be rectangular for shell type transformer.
- The rectangular coil is suitable for small and low voltage transformers.

Why the stepped core is used in place of square core in the large rating transformer?

- The diameter of the circumscribing circle for square / rectangular coil is larger than the diameter of stepped core of same area of cross section therefore the length of mean turns of winding is reduced in the stepped core.
- Therefore the length of mean turns in the stepped core reduced which result in reduction of copper winding cost and copper losses.

- However as the number of steps increases of different sizes, the cost of labour charges for shearing and assembling of different laminations are increases.

Square Coil

Let us consider

- Size of core = a
- Diameter of circumscribing circle = d
- The diameter of circumscribing circle is $d = \sqrt{(a^2 + a^2)} = \sqrt{2}(a)$

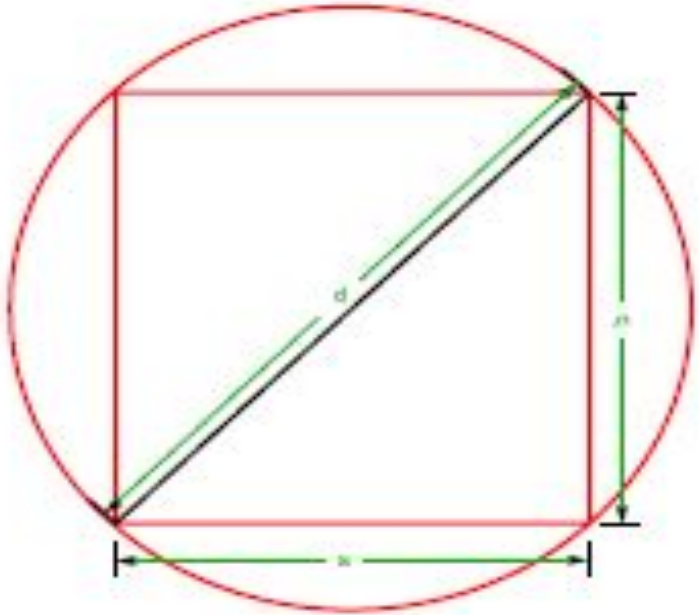


FIGURE : Cross Section of Square Core

Therefore the side of square a = d / $\sqrt{2}$

Gross area of core $A_{gi} = a^2 = (d / \sqrt{2})^2 = 0.5d^2$

Stacking factor = Net core area / Gross core area

Let the stacking factor is 0.9

Net core area = (0.9) * Gross core area

$= (0.9) * 0.5d^2$

$= 0.45d^2$

- Therefore the ratio of net core area to the area of the circumscribing circle

  $= 0.45d^2 / (\pi d^2 / 4)$

  $= 0.58$

- Similarly the the ratio of gross core area to the area of the circumscribing circle $= 0.5d^2 / (\pi d^2 / 4)$

  $= 0.64$

Two Stepped Core

- Let the length of rectangular = a
- Breath of rectangular = b
- Diameter of circumscribing circle = d
- Angle between the length of rectangular and diagonal = θ

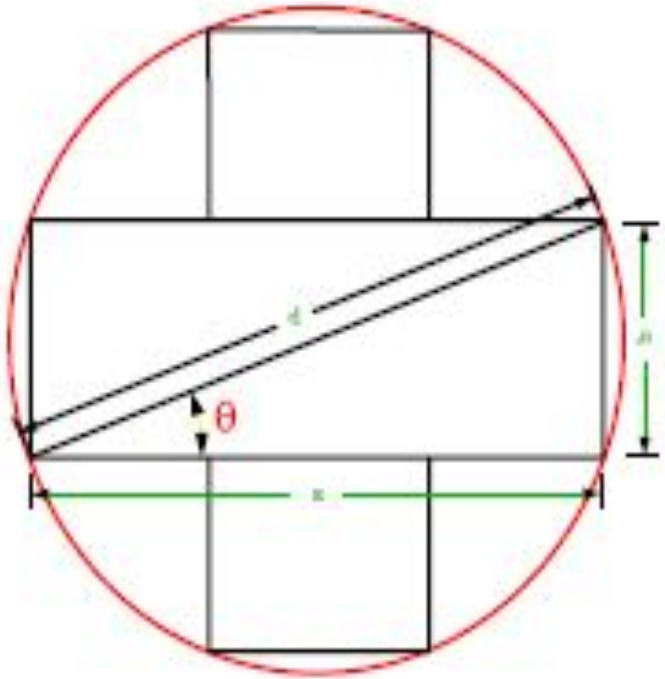
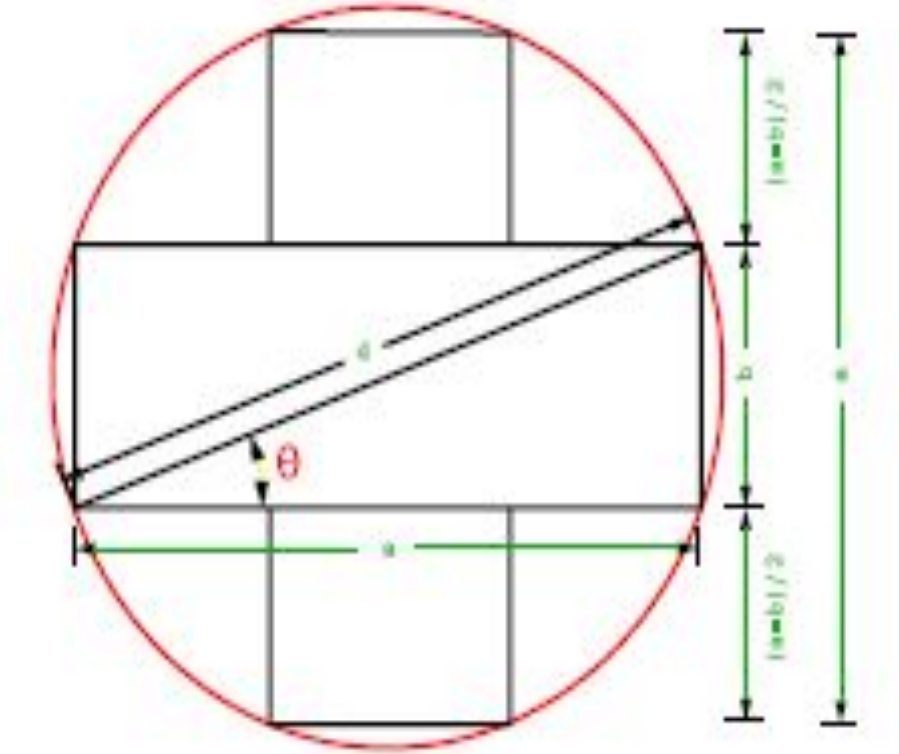


FIGURE : Cross Section of Two Stepped (Cruciform) Core


θ

The two stepped core can be divided into three rectangular parts.

Gross core area $A_{gi} = ab + [(a – b) / 2 * b] + [(a – b) / 2 * b]$

$$A_{gi} = ab + ab – b^2$$

$$A_{gi} = 2ab – b^2 \quad \text{.....(1)}$$

Now $\text{Cos } \theta = a / d$

$$a = d \text{ Cos } \theta \quad \text{.....(2)}$$

$$\text{Sin } \theta = b / d$$

$$b = d \text{ Sin } \theta \text{ ……(3)}$$

Substitute value of a and b in the equation (1)

$$A_{gi} = 2 (d \text{ Cos } \theta) (d \text{ Sin } \theta) – (d \text{ Sin } \theta)^2$$

$$= 2d^2 \text{ Sin } \theta \text{ Cos } \theta – d^2 \text{ Sin}^2 \theta$$

$$= d^2 (\text{ Sin } 2\theta – \text{Sin}^2 \theta)$$

- Differentiate A_{gi} with respect to θ and equating to zero to get maximum core area $d / d\theta (A_{gi}) = 0$

$$d / d\theta (d^2 \text{ Sin } 2\theta – d^2 \text{ Sin}^2 \theta) = 0$$

$$= (2 d^2 \text{ Cos } 2\theta – d^2 2 \text{ Sin } \theta \text{ Cos } \theta) = 0$$

- Therefore $d^2 (\text{Sin } 2 \theta) = 2 d^2 \text{ Cos } 2\theta$

$$(\text{Sin } 2 \theta / \text{Cos } 2\theta) = 2$$

$$\text{Tan } 2\theta = 2$$

$$2\theta = \tan^{-1}(2)$$

$$\theta = [1/2] \tan^{-1}(2)$$

$$= 31.72\ldots.(4)$$

Using equation (2), (3) and (4)

$$a = d \text{ Cos } \theta = \quad = d \text{ Cos } (31.72) = 0.85d$$

$b = d \sin \theta = d \sin (31.72) = 0.53d$

Substitute value of a and b in the equation (1)

$$A_{gi} = 2 (0.85d) (0.53d) – (0.53d)^2$$

$$= 0.618d^2$$

- Stacking factor = Net core area / Gross core area
- Therefore net core area = 0.9 * Net core area

$$= 0.9 * (0.618d^2)$$

$$= 0.56\ d^2$$

- The ratio of net core area to the area of circumscribing circle

$$= 0.56\ d^2 / (\pi\ d^2 / 4) = 0.71$$

- Similarly the ratio of gross core area to the area of circumscribing circle

$$= 0.618d^2 / (\pi d^2 / 4)$$

$$= 0.79$$

Finally We Conclude that

	Square core	Two stepped core (Cruciform core)
Net core area / Area of circumscribing circle	0.58	0.71
Gross core area / Area of circumscribing circle	0.64	0.79

Thank You
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