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K_0,K_1,K_2,K_3 CONSTANTS EVALUATION OF MAGNETO-CRYSTALLINE ANIOSOTROPY ENERGY DENSITY EQUATION OF PURE IRON BASED ON TEXTURE FACTOR FOR IDEAL FIBRES

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1.ABSTRACT:

Texture Factor ,A* and Magnetic Crystalline Anisotropy Energy Density,E* K_0,K_1,K_2, K_3 Constants are important parameters for Pure Iron. While the former indicates volume density of crystals having preferred Orientation, latter indicates the easy and hard magnetization directions. Evaluation of these parameters for Pure Iron and Electrical Steel enables in reduction of core losses and improving the electrical energy efficiency in Transformers, Rotating Machines. In this research article,an attempt is made to compute Magneto-Crystalline Anisotropy Energy Density for pure iron based on Texture Factor for Ideal fibres.

Keywords: Texture Factor, Magnetic Crystalline Anisotropy Energy Density,Core losses

2.INTRODUCTION:

The Magneto Crystalline Anisotropy constants K_0,K_1,K_2, K_3 values determine the extent to which a material is easily magnetizable. Their value depends on Chemical Composition, Crystal Structure,Thermo-Mechanical Processing history of the given material.Texture factor constants K_0,K_1,K_2, K_3 values determines the preferred orientations of grains, the Overall Texture Factor is quantitative measurement of texture. The value signifies extent of presence of standard texture viz. Cube Texture(T.F = 22.5), Goss Texture(T.F = 35.6),Gamma Texture(T.F = 38.68) in the given material

3.ESTIMATION OF MAGNETIC ANISOTROPY CONSTANTS K_0,K_1,K_2,K_3 CONSTANTS EVALUATION OF FOR PURE IRON:

Magneto Crystalline Anisotropy Energy is generally expressed by an expansion into direction cosines α_1, α_2,α_3 of the magnetization with respect to the crystal axes.

$E^* = K_0 + K_1 (\sum\alpha^2_1\, \alpha^2_2) + K_2 (\prod\alpha^2_1) + K_3 (\sum\alpha^2_1\, \alpha^2_2)^2$ [I];

[uvw]	a	b	c	α_1	α_2	α_3	E
[100]	0	90^0	90^0	1	0	0	K_0
[110]	45^0	45^0	90^0	$1/\sqrt{2}$	$1/\sqrt{2}$	$1/\sqrt{2}$	$K_0 + K_1/4$
[111]	54.7^0	54.7^0	54.7^0	$1/\sqrt{3}$	$1/\sqrt{3}$	$1/\sqrt{3}$	$K_0 + K_1/3 + K_2/27$

From REF 1, we have $E^* = 0.355A^* + (0.163 – 0.013A^*)[wt\%Si] - 1.898$

FOR Pure Iron, we have

$E^* = 0.355A^* - 1.898$ [Si% =0 for pure iron] ……..[II]

FOR **A* for ϴ fibre <100>//ND is 22.5 => E* = 6.0895**

FOR **A* for fibre <110>//ND is 35.6 => E* = 10.74**

FOR **A* for ϒ fibre <111>//ND is 38.68 => E* = 11.8334**

$E^* = K_0 + K_1 (\sum\alpha^2_1\, \alpha^2_2) + K_2 (\prod\alpha^2_1) + K_3 (\sum\alpha^2_1\, \alpha^2_2)^2$ …. [I];

FOR [100] directions, $\alpha_1 = 1, \alpha_2 = 0, \alpha_3 = 0 \Rightarrow E = K_0$

- ⇨ FOR [100] directions , $E^* = 6.0895 \Rightarrow$ **$K_0 = 6.0895$**
- ⇨

FOR [110] directions, $\alpha_1 = 1/\sqrt{2}, \alpha_2 = 1/\sqrt{2}, \alpha_3 = 0$

FOR [110] directions, $E^* = 10.74$

- ⇨ $E^* = 6.0895 + K_1/4 + K_3/16$
- ⇨ $10.74 = 6.0895 + K1/4 + K_3/16$
- ⇨ $4.6505 = K_1/4 + K_3/16$
- ⇨ $4K_1 + K_3 = 74.408$ ……[II]
- ⇨ $K_3 = 74.408 - 4K_1$

FOR [111] directions, $\alpha_1 = 1/\sqrt{3}, \alpha_2 = 1/\sqrt{3}, \alpha_3 = 1/\sqrt{3}$

FOR [111] directions, $E^* = 11.8334$

- ⇨ $11.8334 = K_0 + K_1/3 + K_2/27 + K_3/9$
- ⇨ $11.8334 = 6.0895 + K_1/3 + K_2/27 + K_3/9$
- ⇨ $5.7439 * 27 = 9K_1 + K_2 + 3K_3$
- ⇨ $9K_1 + K_2 + 3K_3 = 155.0853$ ……[III]

Substracting 3* [II] - [III]

- ⇨ $12 K_1 + 3 K_3 = 223.224$
  (-)
- ⇨ $9K_1 + K_2 + 3K_3 = 155.0853$
  ____
  $3K_1 - K_2 = 68.1387$
- ⇨ $K_2 = 3K_1 - 68.1387$; $K_3 = 74.408 - 4K_1$
- ⇨ Substituting K_2, K_3 values in ……[III]
- ⇨ **$K_1 = 13.126$; $K_2 = -28.7605$; $K_3 = 21.904$**

GENERLIZED EQUATION FOR $E^* = K_0 + K_1 (\sum\alpha^2_1 \alpha^2_2) + K_2 (\prod\alpha^2_1) + K_3 (\sum\alpha^2_1 \alpha^2_2)^2$ …. [I];

- ⇨ **$E^* = 6.0895 + 13.126(\sum\alpha^2_1 \alpha^2_2) - 28.7605(\prod\alpha^2_1) + 21.904(\sum\alpha^2_1 \alpha^2_2)^2$** …. [IV]

- ⇨ Above is the Standard Magnetic Crystalline Anisotropic Energy Equation for Pure Iron with four **K_0, K_1, K_2, K_3** Constants

CRYSTALLOGRAPHIC DIRECTION	MAGNETO-CRYSTALLINE ANISOTROPY ENERGY DENSITY
[100] $\alpha_1 = 1, \alpha_2 = 0, \alpha_3 = 0$	**$E^*_{[100]} = 6.0895$**
[110] $\alpha_1 = 1/\sqrt{2}, \alpha_2 = 1/\sqrt{2}, \alpha_3 = 0$	**$E^*_{[110]} = 10.74$**
[111] $\alpha_1 = 1/\sqrt{3}, \alpha_2 = 1/\sqrt{3}, \alpha_3 = 1/\sqrt{3}$	**$E^*_{[111]} = 11.8334$**

DISCUSSION:

The <100>//ND fibre accounts for the lowest anisotropy energy since the flux lines, distributed homogenously in a plane of the rotating laminated sheet, have an easiest magnetization direction with the in-plane rotated cube texture components. On the contrary, the ϒ and the <011>//ND fibre orientations have relatively high anisotropy energy and as such, the occurrence of these components in pure iron is undesirable.

4. ESTIMATION OF TEXTURE K_0,K_1,K_2,K_3 CONSTANTS FOR PURE IRON

From [II], we have $E^* = 0.355A^* - 1.898$

GENERLIZED EQUATION FOR TEXTURE FACTOR,$A^* = K_0 + K_1 (\sum \alpha^2_1 \alpha^2_2) + K_2 (\prod \alpha^2_1)) + K_3 (\sum \alpha^2_1 \alpha^2_2)^2$ [I]

$\Rightarrow 0.355A^* - 1.898^* = \mathbf{6.0895 + 13.126}(\sum \alpha^2_1 \alpha^2_2)\ \mathbf{-28.7605}(\prod \alpha^2_1) + \mathbf{21.904}(\sum \alpha^2_1 \alpha^2_2)^2$

$\Rightarrow 0.355A^* = 7.9875 + \mathbf{13.126}(\sum \alpha^2_1 \alpha^2_2)\ \mathbf{-28.7605}(\prod \alpha^2_1) + \mathbf{21.904}(\sum \alpha^2_1 \alpha^2_2)^2$

⇨ $\mathbf{A^* = 22.5 + 36.9746} (\sum \alpha^2_1 \alpha^2_2) - \mathbf{81.0154} (\prod \alpha^2_1) + \mathbf{61.7014}(\sum \alpha^2_1 \alpha^2_2)^2$ **……[IV]**

FOR [100] direction , , $\alpha_1 = 1, \alpha_2 = 0, \alpha_3 = 0$,$A^* = 22.5 \Rightarrow A^* = 22.5$ for Ɵ fibre <100>//ND

FOR [110] direction , $\alpha_1 = 1/\sqrt{2}, \alpha_2 = 1/\sqrt{2}, \alpha_3 = 0$, $A^* = 22.5 + 52.4/4 = 35.6 \Rightarrow A^* = 35.6$ for fibre <110>//ND

FOR [111] direction , $\alpha_1 = 1/\sqrt{3}, \alpha_2 = 1/\sqrt{3}, \alpha_3 = 1/\sqrt{3}$, $A^* = 22.5 + 52.4/3 - 34.74/27 = 38.68 \Rightarrow A^* = 38.68$ for ϒ fibre <111>//ND

5. CONCLUSIONS:

Magneto-Crystalline Anisotropy Energy Density value is least for [100] directions, and higher for [110] & [111] directions. Therefore [100] directions are easy directions of magnetization for pure iron and [111] hardest direction for magnetization of pure iron,[110] direction is harder direction for magnetization of pure iron. Texture Factor Equation results are consistent with the standard results and conforms to the value of ideal fibres.

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