IEC 60205

Edition 3.1   2009-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Calculation of the effective parameters of magnetic piece parts

Calcul des paramètres effectifs des pièces magnétiques

IEC 60205:2006+A1:2009

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

- Catalogue des publications de la CEI: www.iec.ch/searchpub/cur_fut-f.htm

Le Catalogue en-ligne de la CEI vous permet d'effectuer des recherches en utilisant différents critères (numéro de référence, texte, comité d'études,…). Il donne aussi des informations sur les projets et les publications retirées ou remplacées.

- Just Published CEI: www.iec.ch/online_news/justpub

Restez informé sur les nouvelles publications de la CEI. Just Published détaille deux fois par mois les nouvelles publications parues. Disponible en-ligne et aussi par email.

- Electropedia: www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International en ligne.

- Service Clients: www.iec.ch/webstore/custserv/custserv_entry-f.htm

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions, visitez le FAQ du Service clients ou contactez-nous:

Email: csc@iec.ch
Tél.: +41 22 919 02 11
Fax: +41 22 919 03 00

IEC 60205

Edition 3.1   2009-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Calculation of the effective parameters of magnetic piece parts

Calcul des paramètres effectifs des pièces magnétiques

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION
_____

CALCULATION OF THE EFFECTIVE PARAMETERS
OF MAGNETIC PIECE PARTS

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60205 has been prepared by IEC technical committee 51: Magnetic components and ferrite materials.

This consolidated version of IEC 60205 consists of the third edition (2006) [documents 51/848/FDIS and 51/857/RVD] and its amendment 1 (2009) [documents 51/928A/CDV and 51/940/RVC].

The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience.

It bears the edition number 3.1.

A vertical line in the margin shows where the base publication has been modified by amendment 1.

The French version of this standard has not been voted upon.

This edition includes the following significant technical changes with respect to the previous edition:

a) unit of angles through the text are described by using "radian";

b) new words are added in 2.1 "All angles are in radians";

c) replacement, Clause 3.9, of the equation $\dfrac{l_2}{A_2} = \dfrac{\ln d_2 g / d_3}{D\pi(h_1 - h_2)}$ by $\dfrac{l_2}{A_2} = \dfrac{\ln d_2 g / d_3}{D\pi(h_1 - h_2)/2}$;

d) new cores "EL, ER, PQ, EFD and E planar" are added in this edition.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendments will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

• reconfirmed,

• withdrawn,

• replaced by a revised edition, or

• amended.

CALCULATION OF THE EFFECTIVE PARAMETERS
OF MAGNETIC PIECE PARTS

1   Scope

This International Standard lays down uniform rules for the calculation of the effective parameters of closed circuits of ferromagnetic material.

2   Basic rules

The following basic rules are applicable to this standard.

2.1   All results shall be expressed in units based on the millimetre, shall be accurate to three significant figures, but to derive l_e, A_e, and V_e the values of C_1 and C_2 shall be calculated to five significant figures. All angles are in radians.

NOTE   The purpose of specifying this degree of accuracy is only to ensure that parameters calculated at different establishments are identical and it is not intended to imply that the parameters are capable of being determined to this accuracy.

2.2 A_{min} is the nominal value of the smallest cross-section. All the dimensions used to calculate A_{min} shall be the mean values between the tolerance limits quoted on the appropriate piece part drawing.

2.3   Calculations are only applicable to the component parts of a closed magnetic circuit.

2.4   All dimensions used for the purpose of calculations shall be the mean value within the tolerance limits quoted on the appropriate piece part drawing.

2.5   All irregularities in the outline of the core, such as small cut-outs, notches, chamfers, etc. shall be ignored unless otherwise described.

2.6   When the calculation involves the sharp corner of a piece part, then the mean length of flux path for that corner shall be taken as the mean circular path joining the centres of area of the two adjacent uniform sections, and the cross-sectional area associated with that length shall be taken as the average area of the two adjacent uniform sections.

Calculation of effective parameters l_e, A_e and V_e.

The effective parameters can be defined as

$$l_e = C_1^2/C_2 \qquad A_e = C_1/C_2 \qquad V_e = l_e A_e = C_1^3/C_2^2$$

where

l_e is the effective magnetic length of the core (mm);
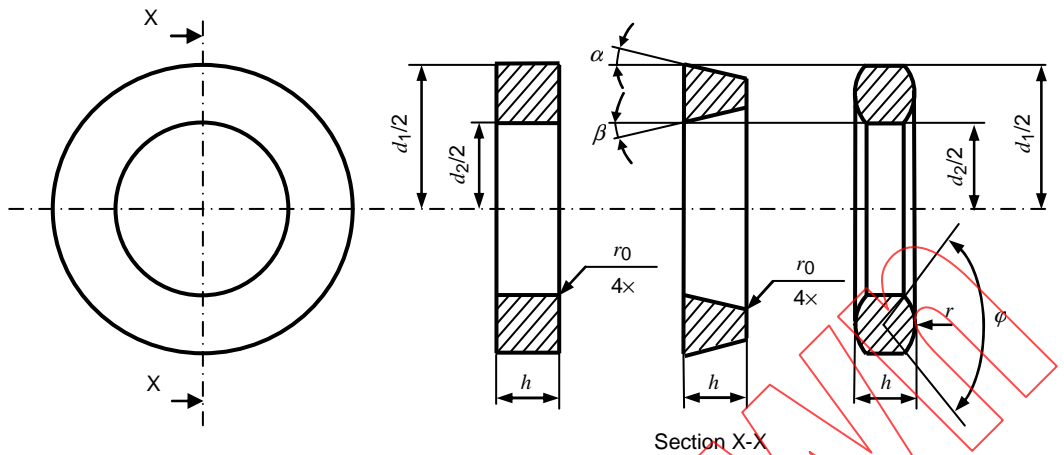
A_e is the effective cross-sectional area (mm^2);

V_e is the effective volume (mm^3);

C_1 is the core constant (mm^{-1});

C_2 is the core constant (mm^{-3}).

3 Formulae for the various types of cores

3.1 Ring cores

Section X-X

IEC 584/06

$$C_1 = \frac{2\pi}{h_e \ln(d_1 / d_2)}$$

$$C_2 = \frac{4\pi(1/d_2 - 1/d_1)}{h_e^2 \ln^3(d_1/d_2)}$$

3.1.1 For ring cores of rectangular cross-section with sharp corners

$$h_e = h$$

3.1.2 For ring cores of rectangular cross-section with an appreciable average rounding radius r_0

$$h_e = h(1 - k_1) \quad k_1 = \frac{1{,}7168 r_0^2}{h(d_1 - d_2)}$$

3.1.3 For ring cores of trapezoidal cross-section with sharp corners

$$h_e = h(1 - k_2) \quad k_2 = \frac{h(\tan\alpha + \tan\beta)}{d_1 - d_2}$$

3.1.4 For ring cores of trapezoidal cross-section with an appreciable average rounding radius r_0

$$h_e = (1 - k_1 - k_2)$$

3.1.5 For ring cores of cross-section with circular arc frontal sides

$$h_e = h - \frac{d_1 - d_2}{4\sin^2(\varphi/2)}\left(2\sin\frac{\varphi}{2} - \frac{\sin\varphi}{2} - \frac{\varphi}{2}\right)$$

$$\varphi = 2\arcsin\frac{d_1 - d_2}{4r}.$$

NOTE   When the winding is uniformly distributed over a ring core, it may be expected that, at all points inside the ring core, the flux lines will be parallel to its surface.

No leakage flux will therefore leave or enter the ring core. This justifies the use of a theoretically more correct derivation of the effective parameters which does not make use of the assumption that the flux is uniformly distributed over the cross-section.

3.2 Pair of U-cores of rectangular section

NOTE   U + PLT (Plate)-cores use U core formulas.
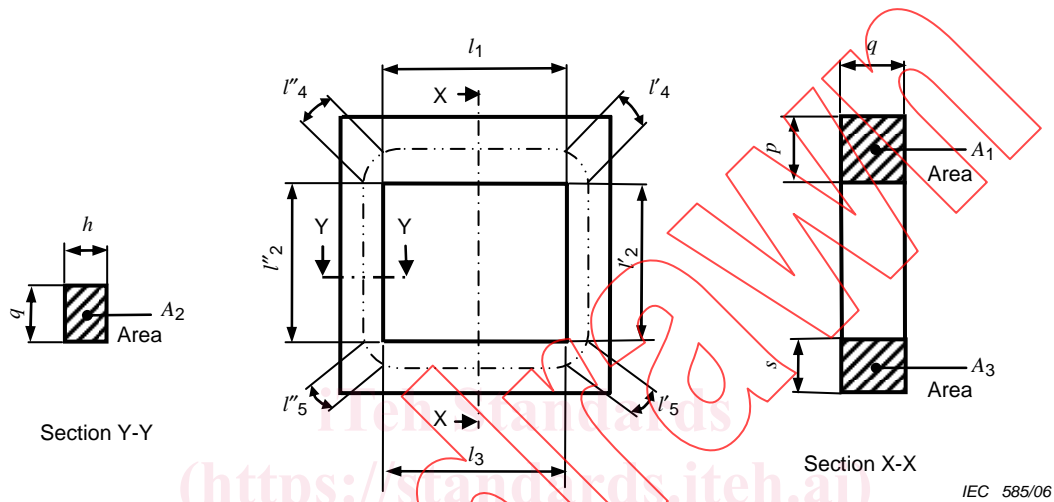
IEC   585/06

Length of flux path associated with area A_2:

$$l_2 = l_2' + l_2''$$

Mean length of flux paths at corners:

$$l_4 = l_4' + l_4'' = \frac{\pi}{4}(p + h)$$

$$l_5 = l_5' + l_5'' = \frac{\pi}{4}(s + h)$$

Mean areas associated with l_4 and l_5:

$$A_4 = \frac{A_1 + A_2}{2}$$

$$A_5 = \frac{A_2 + A_3}{2}$$

$$C_1 = \sum_{i=1}^{5}\frac{l_i}{A_i} \qquad C_2 = \sum_{i=1}^{5}\frac{l_i}{A_i^2}$$

3.3 Pair of U-cores of rounded section

NOTE   U + PLT (Plate)-cores use U core formulas.

In calculating A_2 ignore any ridges introduced for the purpose of facilitating manufacture.

Length of flux path associated with area A_2:

$$l_2 = l_2' + l_2''$$

Mean length of flux path at corners:

$$l_4 = l_4' + l_4'' = \frac{\pi}{4}(p + h)$$

$$l_5 = l_5' + l_5'' = \frac{\pi}{4}(s + h)$$
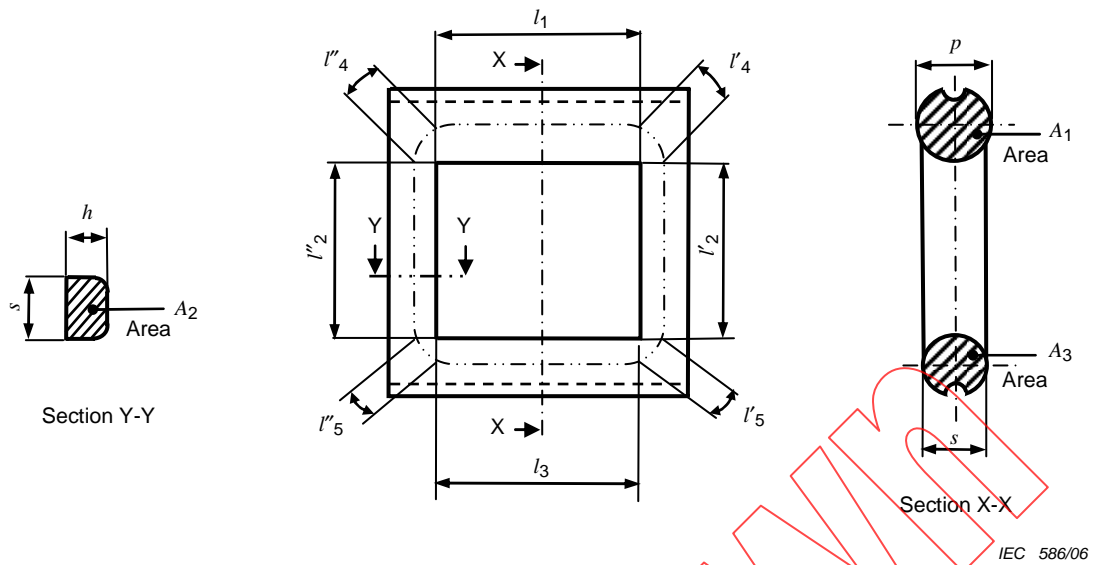
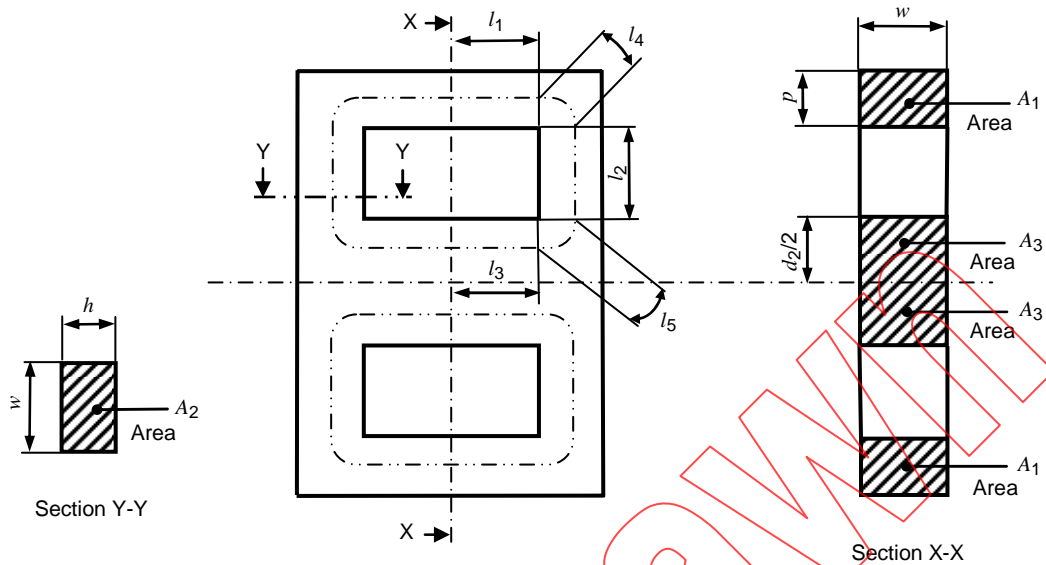Mean areas associated with l_4 and l_5:

$$A_4 = \frac{A_1 + A_2}{2}$$

$$A_5 = \frac{A_2 + A_3}{2}$$

$$C_1 = \sum_{i=1}^{5} \frac{l_i}{A_i} \qquad C_2 = \sum_{i=1}^{5} \frac{l_i}{A_i^2}$$

3.4 Pair of E-cores of rectangular section

NOTE E + I (Plate)-cores use E core formulas.

IEC 587/06

Section Y-Y

Section X-X

Area of half the centre limb: A_3

Mean length of flux paths at corners:

$$l_4 = \frac{\pi}{8}(p+h)$$

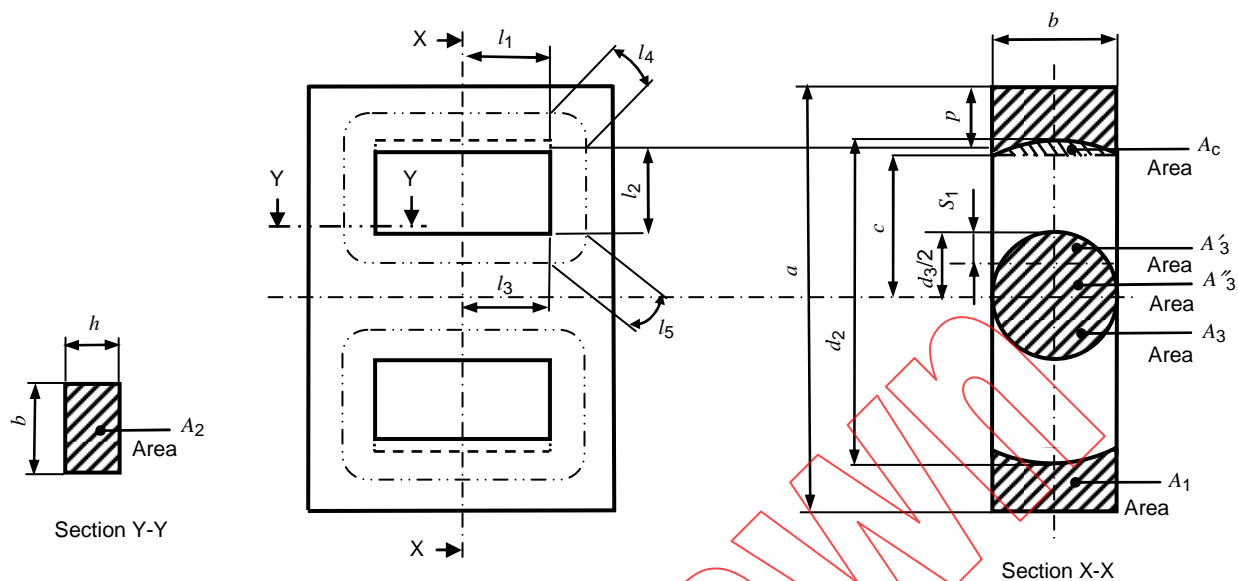$$l_5 = \frac{\pi}{8}\left(\frac{d_2}{2}+h\right)$$

Mean areas associated with l_4 and l_5:

$$A_4 = \frac{A_1 + A_2}{2}$$

$$A_5 = \frac{A_2 + A_3}{2}$$

$$C_1 = \sum_{i=1}^{5}\frac{l_i}{A_i} \qquad C_2 = \sum_{i=1}^{5}\frac{l_i}{2A_i^{\,2}}$$

3.5   Pair of ETD/EER-cores

Section Y-Y

Section X-X

IEC 588/06

A_1 is equal to the rectangle $b\left(\dfrac{1}{2}a-c\right)$ less the cap or segment A_c.

$$A_C = \frac{1}{4}d_2^{\;2}\left[\arcsin\left(\frac{b}{d_2}\right)\right] - \frac{1}{4}b\sqrt{d_2^{\;2}-b^2}$$

$$A_1 = \frac{1}{2}ab - \frac{1}{4}b\sqrt{d_2^{\;2}-b^2} - \frac{1}{4}d_2^{\;2}\arcsin\left(\frac{b}{d_2}\right)$$

Mean length of flux path at back walls:

$$l_2 = \frac{1}{4}\left(d_2 + \sqrt{d_2^{\;2}-b^2}\right) - \frac{d_3}{2}$$

NOTE l_2 is taken from the mean value of $\dfrac{1}{2}(d_2 - d_3)$ and $\left(c - d_3/2\right)$.

Area of half the centre limb:

$$A_3 = A_3' + A_3''$$

The condition to obtain $A_3' = A_3''$ is

$$S_1 = 0{,}2980d_3$$

Mean length of flux path at corners:

$$l_4 = \frac{\pi}{8}(p + h)$$

where $p = \dfrac{a}{2} - l_2 - \dfrac{d_3}{2}$
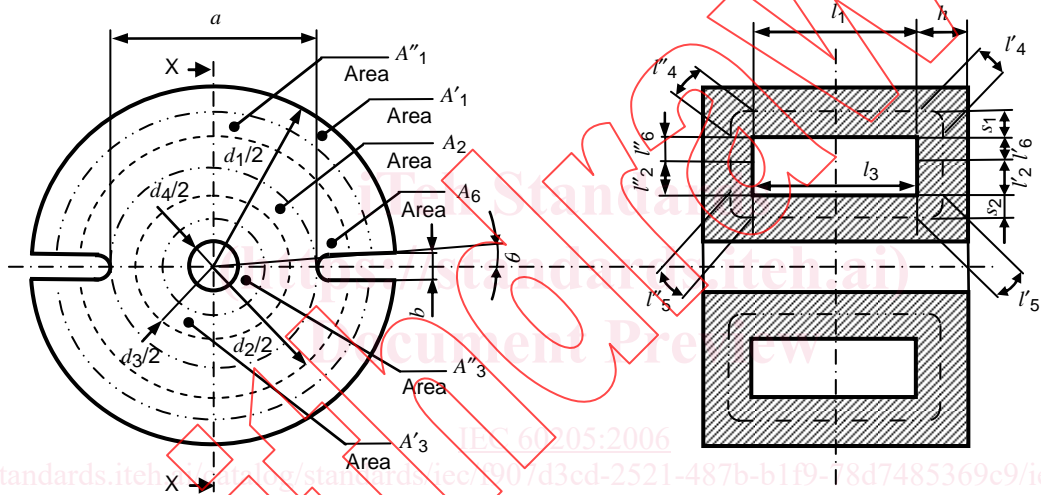
$$l_5 = \frac{\pi}{8}(2S_1 + h)$$

Mean areas associated with l_4 and l_5:

$$A_4 = \frac{A_1 + A_2}{2}$$

$$A_5 = \frac{A_2 + A_3}{2}$$

$$C_1 = \sum_{i=1}^{5} \frac{l_i}{A_i} \qquad C_2 = \sum_{i=1}^{5} \frac{l_i}{2A_i^2}$$

3.6 Pair of pot-cores

Section X-X

IEC 589/06

Area of outer ring:

$$A_1 = A_1' + A_1''$$

The condition to obtain $A_1' = A_1''$ is

$$S_1 = -\frac{d_2}{2} + \sqrt{\frac{1}{8}\left(d_1^2 + d_2^2\right)}$$

Area of centre limb:

$$A_3 = A_3' + A_3''$$

The condition to obtain $A_3' = A_3''$ is

$$S_2 = \frac{d_3}{2} - \sqrt{\frac{1}{8}\left(d_3^2 + d_4^2\right)}$$

Area of ring:

$$A_1 = \frac{1}{4}(\pi - n\theta)\left(d_1^{\,2} - d_2^{\,2}\right)$$

$$\theta = \arcsin\frac{2b}{d_1 + d_2}$$

where

b is the slot width;

n is the number of slots.

Core factors associated with l_2:

$$\frac{l_2}{A_2} = \frac{1}{\pi h}\ln\frac{a}{d_3}$$

$$\frac{l_2}{A_2^{\,2}} = \frac{a - d_3}{\pi^2 a d_3 h^2}$$

Area of centre limb:

$$A_3 = \frac{\pi}{4}\left(d_3^{\,2} - d_4^{\,2}\right)$$

Mean length of flux paths at corners:

$$l_4 = l_4' + l_4'' = \frac{\pi}{4}(2S_1 + h)$$

$$l_5 = l_5' + l_5'' = \frac{\pi}{4}(2S_2 + h)$$

Areas associated with l_4 and l_5:

$$A_4 = \frac{1}{8}(\pi - n\theta)\left(d_1^{\,2} - d_2^{\,2}\right) + \frac{\pi}{2}d_2 h$$

$$A_5 = \frac{\pi}{8}\left(d_3^{\,2} - d_4^{\,2} + 4d_3 h\right)$$

Core factors associated with l_6:

$$\frac{l_6}{A_6} = \frac{1}{(\pi - n\theta)h}\ln\frac{d_2}{a}$$

$$\frac{l_6}{A_6^{\,2}} = \frac{d_2 - a}{a d_2 (\pi - n\theta)^2 h^2}$$

$$C_1 = \sum_{i=1}^{6}\frac{l_i}{A_i} \qquad C_2 = \sum_{i=1}^{6}\frac{l_i}{A_i^{\,2}}$$