Analytical field calculations of skewed magnets

Citation for published version (APA):

Document status and date:
Published: 01/01/2012

Document Version:
Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license above, please follow below link for the End User Agreement:
www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:
openaccess@tue.nl
providing details and we will investigate your claim.
Analytical Field Calculations of Skewed Magnets

Maarten F. J. Kremers, Johannes J. H. Paulides, Esin Ilhan and Elena A. Lomonova
Electromechanics and Power Electronics Group, Eindhoven University of Technology
Eindhoven, 5612AZ, The Netherlands
Email: m.f.j.kremers@tue.nl

Abstract—Iron core permanent magnet linear actuators are applied in high precision systems and transport applications where a low force ripple is required. Force ripple can be reduced by applying skewing. This paper develops analytical expressions for the magnetic field of skewed magnets. These expressions are used to calculate the magnetic flux density distribution in the air gap and determine the EMF of the actuator.

I. INTRODUCTION

Iron core linear permanent magnet synchronous motors are often applied in high precision positioning systems and transportation applications where a high mean force must be combined with a low force ripple. In order to reduce the force ripple produced by such actuators, several techniques can be applied such as using quasi-Halbach magnetization, pole shifting or skewing. This paper focusses on permanent magnet skewing. Although this method allows reduction of the force ripple, it also affects the mean output force. In order to effectively predict the effects of key design parameters on the performance of the linear actuator shown in Figure 1, accurate and fast models are necessary in order to select the appropriate machine topology. In literature, three dimensional analytical expressions for the magnetic field are available for magnet assemblies with cylindrical [1], triangular [2], or cuboidal [3] permanent magnets. However, there are no analytical expressions available for the field induced by skewed permanent magnets.

II. MAGNETIC SURFACE CHARGE MODEL

In the magnetic surface charge method, 3D analytical expressions for the magnetic field induced by a permanent magnet are deducted from Maxwell’s equations. Under the assumption that the magnetization of a magnet is uniform and the relative permeability $\mu_r = 1$ in the whole model, a scalar potential which imposes a virtual charge distribution on the magnet surfaces is introduced. The analytical magnetic field expressions are obtained using

$$B = \frac{\mu_0}{4\pi} \oint_S \frac{\sigma (\mathbf{r} - \mathbf{r}')}{|\mathbf{r} - \mathbf{r}'|^3} dS'.$$  \hspace{1cm} (1)

These highly accurate field expressions are used to calculate the air gap flux density and the EMF of the actuator. Figure 2 shows the magnetic field component of a permanent magnet which is magnetized along the z-axis.

III. CONCLUSION

Three-dimensional analytical expressions are derived for the magnetic field density of a skewed magnet along the x-, y-, and z-axis. The obtained expressions are used to calculate the flux density distribution in the air gap of the machine and can be used to quickly determine the performance of a skewed actuator design.

REFERENCES