Improvement of Electric Motor Efficiency (Induction Motor) by using Nanocrystalline soft Magnetic alloy as core Material

Mr. Suresh R. Sharda
Research Scholar- GTU

Dr. Chetan . D. Kotwal
Professor- EE Dept
SVIT -Vasad

Abstract— Nanocrystalline soft magnetic Fe-Si-B-P-Cu alloys with high iron-content of 93∼94 wt.% "NANOMET®" exhibit high saturation magnetic flux density (Bs > 1.8 T), low coercively (Hc < 10 A/m) and low core loss (W1.7/50 ∼ 0.4 W/kg) even in a ribbon form with a thickness of up to 40 µm. NANOMET®" provides expected applications that are demanded in the field using strong magnetic fields because of its low core loss and high.

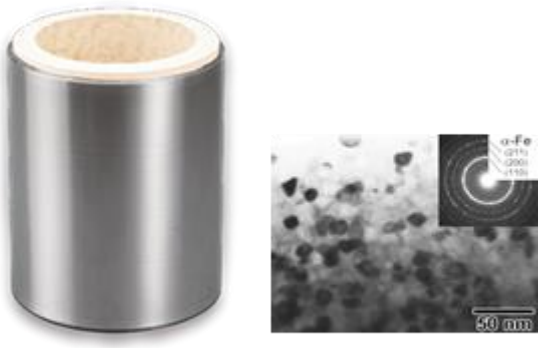
In particular, it is found that brushless Permanent magnet synchronous motor using NANOMET® core exhibited remarkable improvement in energy Consumption. The 50KW, 1500 RPM PMSM with lamination of thickness of 50 mm V/S laminated Nano-crystallized NANOMET® ribbons was designed, simulated and analyzed in JMag software. Core-loss for the designed motor was improved from 204Wto 13.31W and there is about 14% reduction in mass (kg) only by replacing the non-oriented Si-steel core with NANOMET® one. The overall motor efficiency is evaluated to be 2% improvement. In this work, output Characteristics of motor will also be presented.

Keywords—Soft Magnetic Materials, Nanomet, IPM, Torque, Core loses. Efficiency.

I. INTRODUCTION

Due to energy saving, all the appliances or industrial power sources are strongly required to having high efficiency and low energy consumption. One of the solutions is reducing the loss in energy conversion between magnetic and electrical

In late 60's, ferromagnetic amorphous alloys [1] have been developed to meet such requirements. Due to their low core- loss properties, the Fe-based amorphous alloys with a typical system of Fe-Si-B have attracted a lot of industrial interests for practical use [2], While the relatively low Bs of up to 1.6 T as compared to the Si-steel, amorphous alloys are applied to axial-gap motors [3] as core materials and the motors have successfully been commercialized [4]. By making efforts for properties improvements of soft-magnetic alloys, a number of ferromagnetic nanocrystalline alloys, namely, Fe-Si-B-Nb-Cu (FINEMET®) [5] and Fe-(Zr, Nb)-B (NANOPERM®) [6] have been developed. In general, these nanocrystalline alloys exhibited insufficient Bs in spite of their extra-low core loss properties. Consequently, innovative soft magnetic alloys having high Bs as comparable to Si-steel and low W as well matched for amorphous or nano crystalline alloys are required. More recently a series of new nanocrystalline alloys, NANOMET® [7-9], have been developed. These nanocrystalline alloys exhibited high Bs of exceeding 1.8 T. Figure 1(a) and Figure 1 (b). Compositional optimization of metalloid elements contributes marginal amorphous formation by melt-spinning technique even its unusual high Fe content. In addition, the alloys also exhibit outstandingly low W properties By utilizing these excellent magnetic properties, the performance of prototype transformer using wound core of NANOMET® ribbons have already reported [10].



Saturation magnetic flux density (Bs) > 1.8T
Hc (coercivity) <10A/m

Figure 1 (a)

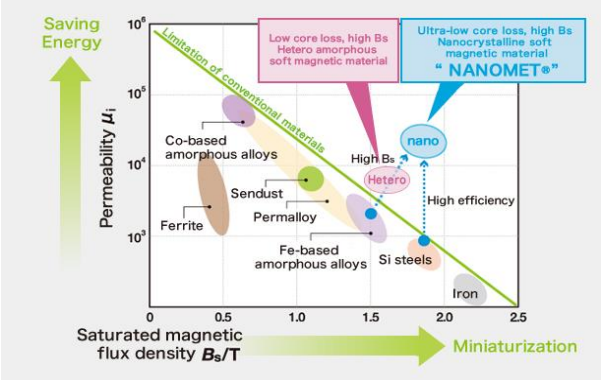


Figure 1 (b)

In this paper, it is intend to present the core loss analysis of permanent magnet motor (IPM) of rating of 50KW, 1500 rpm designed as redial-gap type motor with lamination of 50 mm and using NANOMET® ribbon [11].

II. RESEARCH METHOD

For simulation JMAG-Express software were used with Quick mode option. Feature of software is to evaluate basic motor properties by simply entering geometry template, materials, winding, and drive conditions parameters, also evaluate torque, efficiency, loss, and inductance properties with a graph or numerically. Analysis was done for two different motors of 50 KW, 1500 rpm, IPM with interior permanent magnet rotor and distributed stator winding, designed with laminated core of thickness of 50 mm and Nanocrystalline soft magnetic Fe-Si-B-P-Cu alloys with high iron-content of 93～94 wt.%"NANOMET®".

III. RESULT AND DISCUSSION

The output characteristics of JMag software for efficiency of above designed motor with silicon steel core is shown in figure2(a) and with NANOMET® in figure 2(b) , same for iron losses is shown in figure 3(a) and 3 (b) respectively

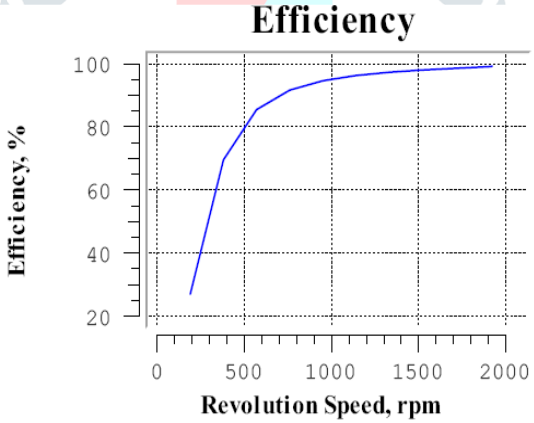


Figure 2 .a

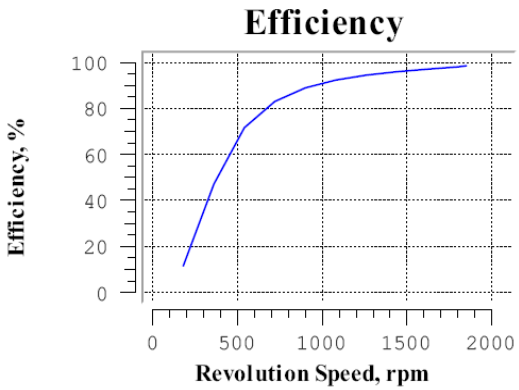


Figure 2.b

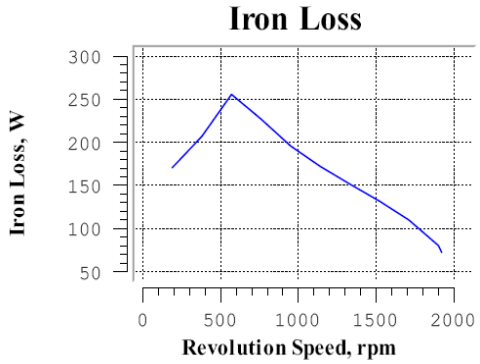


Figure 3 .a

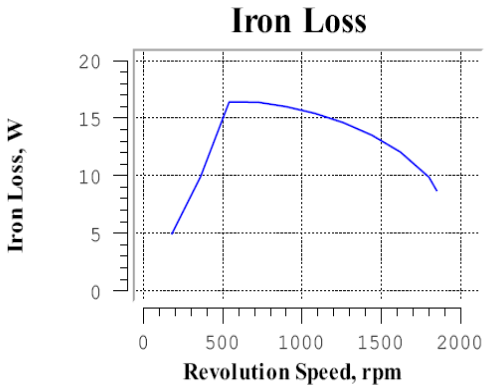


Figure 3.b

TABLE I. COMPARISON FOR COPPER LOSSES, IRON LOSSES, MASS IN KG AND EFFICIENCY FOR IPM MOTOR WITH DIFFERENT CORE MATERIALS

Core Materials	Silicon Steel with 50 mm thickness	NANOMET®
Copper Loss, W	**4129**	**2616**
Iron Loss, W	**204**	**13.31**
Mass Kg	**51.94**	**44.99**
Efficiency, %	**93.81**	**96.09**

Table I summarizes as with use of Nanomet as core material there is Lot of Reduction in iron loss and appreciable reduction of overall mass of motor. Taking the fact that there is more than 2% improvement of overall efficiency for the motor, the remarkable improvement in overall efficiency of the motor suggests that the NANOMET® core is promising material for future motors having low energy consumption property. The maximum potential of the

Innovative motor using the NANOMET® core will be fabricated in the near future.

IV. CONCLUSIONS

To clarify the performance of Fe-based nanocrystalline alloy "NANOMET®" for motor applications, 50 KW brushless IPM motor was Design using laminated NANOMET® core. The obtained results are summarized as follows

(1) Using laminated NANOMET® core, brushless IPM motor with a core outer diameter of 200 mm and a thickness of 98 mm was designed.

(2) Core-loss for the designed motor was improved from 204 W to 13.3 1W only by core material replacing the non-oriented Si-steel with NANOMET®.

(3) Under the rated condition of an applied load torque and revolutions of 1500 rpm, the design motor exhibited remarkably overall efficiency of 2.28% improvement.

These results suggests that the NANOMET® is a promising core material to realize innovative motors with outstandingly high-energy efficiency

ACKNOWLEDGMENT

This work was supported by JMAG-Express FEM software, JMAG Division, JSOL Corporation Harumi Center Building 7F, 2-5-24, Harumi, Chuo-ku, Tokyo 104-0053, Japan for providing online license.

REFERENCES

[1] Duwez, P & Lin, S. C. H. , " Amorphous Ferromagnetic Phase in Iron-Carbon-Phosphorus Alloys," AIP, Journal of Applied Physics, vol.38(10), p.4096–4097,1967

[2] F.E. Luborsky, "Applications of Amorphous Alloys," IEEE*Transaction on Magnetics*, vol. MAG-14, Sept. 1978, pp. 1008–1012.

[3] Z. Wang, Y. Enomoto, M. Ito, R. Masaki, S. Morinaga, H. Itabashi, and S. Tanigawa, "Development of a permanent magnet motor utilizing amorphous wound cores," IEEE Transactions on Magnetics, Vol. 46, Issue 2, February 2010, pp. 570-573.

[4] New letter Hitachi, Ltd, Tokyo, " Highly efficient industrial 11kW permanent magnet synchronous motor without rare-earth metals," Issue on 11 Apri l2012. http://www.hitachi.com/New/cnews/120411.pdf.

[5] Yoshizawa, Y., Oguma, S. and Yamauchi, K.,"Soft Magnetic Alloys Composed New Fe-Based of Ultrafine Grain Structure,"AIP, Journal of Applied Physics, Vol 64, Issue 10, November 1988.

[6] K. Suzuki, A. Makino, N. Kataoka, A. Inoue, and T. Masumoto, " High Saturation Magnetization and Soft Magnetic Properties of bcc Fe–Zr–B and Fe–Zr–B–M (M=Transition Metal) Alloys with Nano scale Grain Size" JIM , Materials Transactions, Vol. 32, Issue 1, pp. 93 -102,1991

[7] A. Makino, T. Kubota, K. Yubuta, A. Inoue, A. Urata, and K. Matsumoto, "Low core losses and magnetic properties of Fe85-86Si1-2B8P4Cu1 nanocrystalline alloys with high B for power applications", AIP ,Appl. Phys,Vol. 109, Isuue 07 , P. A302-1-5, March 2011

[8] A. Makino, " Nano crystalline soft magnetic Fe-Si-B-P-Cu alloys with high B of 108-1.9T contributable to energy saving," IEEE Trans. Magn. Vol.48, Issue 4, pp.1331-1335, April 2012

[9] K. Takenaka, M. Nishijima, and A. Makino, "Effect of Metalloid Elements on the Structures and Soft Magnetic Properties inFe85.2SixB14−x−yPyCu0.8Alloys," IEEE Trans. Magn. Vol. 50, Issue 4, Article Sequence No.2004704, April 2014.

[10] K. Takenaka, N. Nishiyama, A. D. Setyawan, P. Sharma, and A. Makino, "Performance of a prototype power transformer constructed by nano crystalline Fe-Co-Si-B-P-Cu soft magnetic alloys," AIP,J. Appl. Phys. Vol.117, Issue 17 No. D519 , April 2015

[11] N. Nishiyama, K. Tanimoto, and A. Makino, "Outstanding efficiency in energy conversion for electric motors constructed by nanocrystalline soft magnetic alloy NANOMET®" cores," AIP ADVANCES,J. Appl. Phys,Vol.6, Issue 5, No.5925 , March 2016.

.