International Journal on Recent and Innovation Trends in Computing and Communication
Volume: 3 Issue: 11
ISSN: 2321-8169
6452 - 6455

Electromagnetic Analysis of Solenoid Coil in ANSYS and IES Software : Case Study

Mr. J.B.Solanki
Lecturer, B.& B. Institute of Technology,
Vallabhvidyanagar. Anand, Gujarat, INDIA
Email: jayraj_ee@yahoo.co.in

***Abstract* -** The aim of this paper is to get theory technical knowledge of designing a electromagnetic solenoid coil and ogy of verifying induced current in solenoid coil by using ANSYS Software and IES software. For this purpose a 0.3 T coil has been designed with a Poloidal shaped 1500 turn outer coil of 200 cm diameter. To verify such induced current analysis is a challenging task, theoretically which can be equally calculated by a FINITE ELEMENT ANALYSIS package and IES (Integrated Engineering Software) , so a same dimension, assembly and has been modeled and meshed in ANSYS 11.0 FEA package and IES (integrated engineering software) with same load data as given in the software. Theoretical and Simulation results have been compared.

Index Terms :*Electromagnetic Solenoied coil, FEA, IES, ANSYS Software..*

*****

I. Introduction

In section 2 Design the Solenoid coil as electromagnetic coil according to requirement 0.37 T in outer coil[1],[2]. The Solenoid coil can be wound in one or two layers .A solenoid coil with an even number of layers has the advantage of having both leads from the coil come out at the same end of the coil package.there are No. of accepted way to winding Thin Solenoid coils so that they have more current per unit length at the Solenoid ends than in the center .[4]

Before issuing the solve command, the analysis type must be set to modal and the frequency range must be defined. Since the target frequency is usually fairly well known, the range should be limited. It is also important to specify that the modes be extracted , meaning that ANSYS calculates not just frequency, but also element results.[5]

Design the Solenoid coil for 0.37 T magnetic field at centre. Then one single turn coil keep out side the inner coil. Solenoid Coil wound on one small nylon rod having diameter 300cm.

In this paper electromagnetic analysis made on thin solenoid with help of ANSYS software and IES software (integrated engineering software). Result of Magnetic field at center of thin solenoid have been compared in both software.

They work according to electromagnetic principle, which says that a magnetic field is induced by moving charges. The magnetic field excites reluctance forces at boundaries of material with different magnetic permeability's.

II. Thin Solenoied

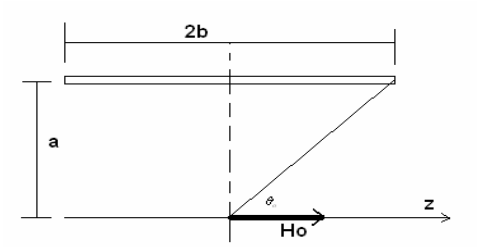

Fig 1 : Thin Solenoid Coil

The Number of ampere turn required to produce a uniform magnetic field at center of solenoid can be calculated by using the following equation

$NI = B_0 L / \mu_0$

Where NI is Total number ampere turn in Solenoid
B0 , Magnetic field at center of Solenoid
L ,length of Solenoid
Permeability of air μ0 = 4π *10-7 H m-1

Underestimate the ampere –turns required to get the magnetic induction in the solenoid anywhere from 3 % to 30 % depending on the Solenoid .As a starting point we take the field of the elemental loop of figure 2 .The field on the axis of this loop can be written as [1,2]

$$H_{z(z,0)} = \frac{2\pi I'}{10} \frac{a^3}{(a^2+z^2)^{3/2}}$$

$$\left(I' = \frac{NI}{2b} \right) \text{…………………..(1)}$$

Where H = field in the orsteds
I = current in the loop in amperes
a = radius of elemental loop
z = point on z axis at which field is measured

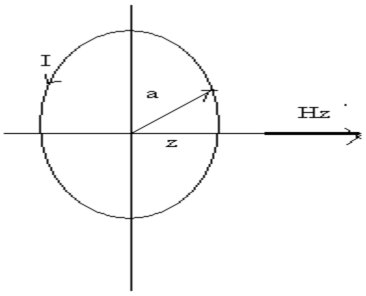

Fig 2 : Definition of parameters for the elemental loop

The central field of such a loop H_0 ,is

$$H_0 = \frac{2\pi I'}{10}\frac{1}{a}$$

……………………………….(2)

And can therefore be written as

$$H_{z(z,0)} = Ho\frac{a^3}{(a^2+z^2)^{3/2}} \quad \text{………………………..(3)}$$

The current loop can be thought of as an elemental of a larger coil and can form the basis for subsequent integration

Magnetic field intensity at centre of coil is given by the

$$H_0 = \frac{4\pi I'}{10}\frac{\beta}{\sqrt{(1+\beta^2)}}$$

Where , $\left(I' = \frac{NI}{2b}\right)$

$$\beta = b/a$$

Magnetic field intensity at centre Z axis

$$H_z = H_0\frac{a^3}{(a^2+z^2)^{3/2}}$$

Magnetic field at center Z axis

$$B_z = \frac{H_z}{1000}$$

Where $\beta = b/a$

H_0 = Field at the center
H_z = Field along z axis
B_z = Flux Density along z- axis
Bz = Magnetic flux density at point on z axis.
NI = Total Ampere-Turns

III. Electromagnetic Analysis of Thin Solenoid in ANSYS

ANSYS Multi physics is a powerful interactive environment for modeling and solving all kinds of scientific and engineering problems based on partial differential equations (PDEs). To solve the PDEs, ANSYS Multi physics uses the proven finite element method (FEM) [8]. The software runs the finite element analysis together with adaptive meshing and error control using a variety of numerical solvers. The user can perform a various types of analysis including stationary and time dependent analysis, linear and nonlinear analysis, eigen frequency and modal analysis[9]

4.1 DATA:
Element Used : Plane 53 (2D)
Option : Axis symmetric
Material Properties : air - Relative Permeability = 1
Coil -Relative Permeability =1
Resistivity = 1.7241E-8 *m* . Ω

4.2 Modeling :
Dimensions:
a = 200 cm b = 150 cm
N = 1500 I = 1000A
Distance z-axis -150 to 150 cm
Applied Boundary condition : Flux parallel at outer boundary
Meshed Model
Flux Density Plot (Nodal Solution)

4.3 Plot result of thin solenoid coil

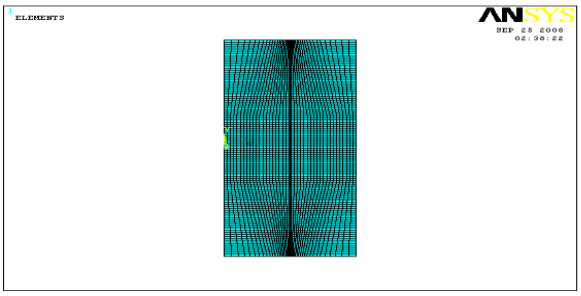

Fig:3 . 3D meshing of thin solenoid coil (1000 bricks)

The model of coil is meshed with 1000 solid 93 brick elements. A Solenoid coil is modeled & meshed in ANSYS 11.0 software Package with Plastic rod. To have proof of concept a transient analysis is done applying same load as in IES software.

Developing an acceptable mesh is very an iterative process. Although it will later be given that electromagnetic results are fairly and better insensitive to mesh size, surface heat flux is highly dependent on the high mesh density at the vacuum boundary surface. For this reason, it is advantageous to make a fine mesh in critical areas on the boundary surfaces (such as near high power HOM ports), while retaining a larger mesh in the body in order to reduce run time and memory usage. A simple way to achieve this mesh variation is to divide the vacuum volume into sub-volumes depending on the needed local mesh size. In this way, not only can the surface mesh be controlled by sizing areas and lines, but the "global" mesh size can be set on a local basis for each sub-volume, resulting in better mesh control.

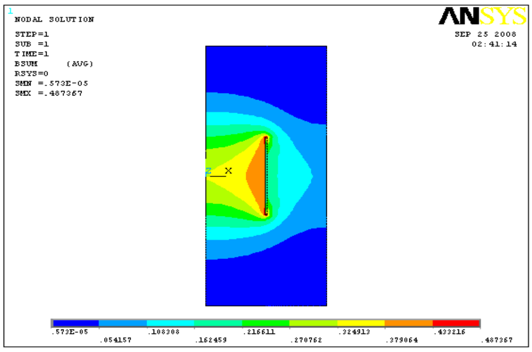

Fig: 4 flux density plot of thin coil

Once the heat flux loads have been applied and all desired electromagnetic quantities have been calculated. It has already been mentioned that global electromagnetic quantities vary only slightly with large changes in mesh density; this is not the case, however, for local effects, such as maximum surface heat flux.[7]

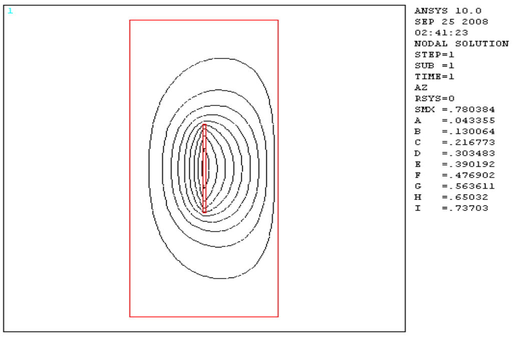

Fig: 5 flux line plot of thin coil

After the HF119 mesh (or HF120, for brick models) has been created, the material properties are set and the boundary conditions defined. In ANSYS, high frequency electromagnetic analyses default to MKS units, and the properties of the resonating material are given as ratios to the free space permittivity and permeability (in this case vacuum is the material, so these properties are both 1). Boundary conditions can be defined in two possible ways: first, as electric walls on the vacuum/cavity interface surfaces, or second, as electric walls with impedance conditions. [7]

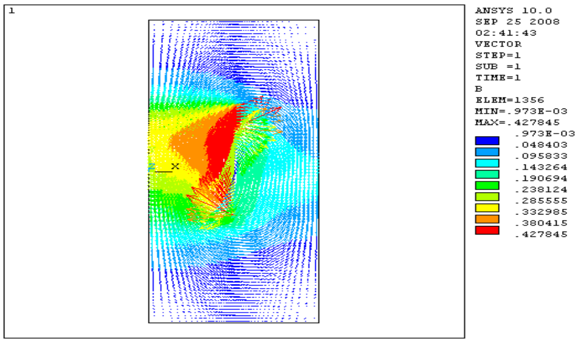

Fig 5 : vector plot of thin coil

It is known that FEA analysis needs a particular air boundary limit to give out results. It was taken under consideration that while including air as an assembly the result was coming finer while increasing the air volume. Air volume has been optimized for a tolerable out put results.[3]

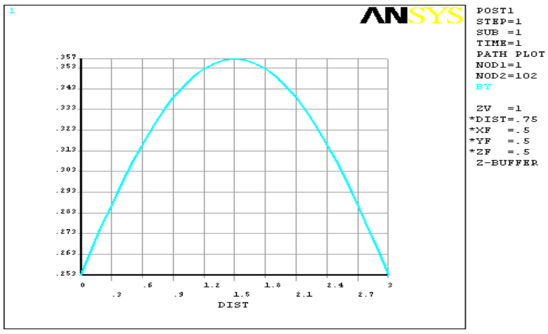

Fig 6: Flux Density along z-axis of thin coil

IV. IES APPROACH FOR THIN SOLENOID COIL (2D)

Integrated Engineering Software (Integrated), a Canadian research and development organization, provides the engineering community with electromagnetic CAE software tools. All of Integrated's seven CAE products are based on the innovative Boundary Element Method (BEM) – an excellent alternative to the more common Finite Element Method (FEM). Integrated's two dimensional (2D) and three dimensional (3D) electromagnetic software enables engineers to understand their designs prior to prototyping. The software allows the engineer to test various physical and material configurations, examine new design concepts, and optimize designs for a wide variety of electromagnetic applications.

Electromagnetic computer-aided engineering software is becoming a standard tool in the solenoid design process, as exemplified by BWS' successful use. In particular, BEM-based electromagnetic software tools
from Integrated Engineering Software offer engineers a proven and effective method for reducing design costs and optimizing solenoid designs.[9]

4.1 MODEL:

Type of Element: **2D brick**

No. of Elements: **80**

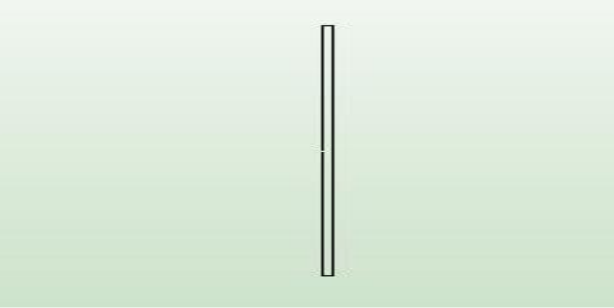

Figure 1 : Model of Thin solenoid coil

First, a CAD model is created using Magneto's built-in CAD system. User's also have the option of reading in IGES or DXF format geometry files from other standard CAD systems. Taking advantage of Magneto's rotationally symmetric option allows BWS to greatly simplify the design in terms of modeling and simulation time . Second, the physical properties are defined (e.g. materials and sources). The solenoid's coil winding is modeled by specifying 80A Amp Turns in the coil region. The last step before analysis involves placing Boundary Elements only on the surface of material interface in contrast to the Finite Element Method that requires elements in an entire design region.[9]

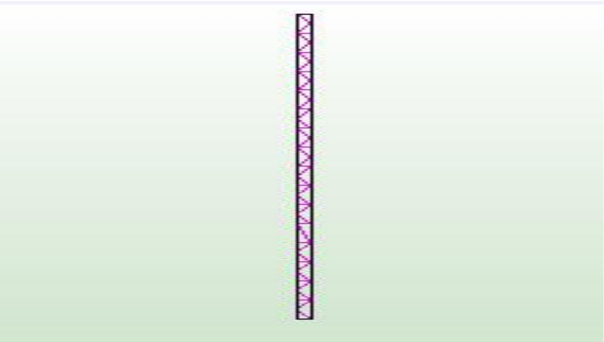

Figure 2: IES Meshing of Thin solenoid coil

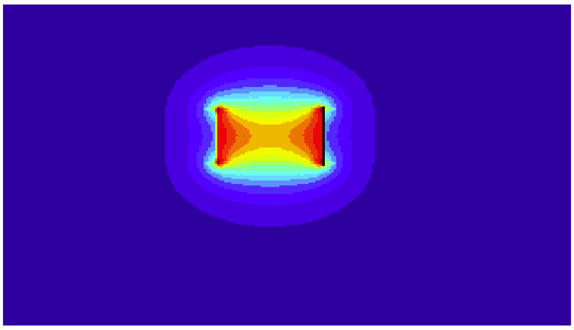

Figure 3:Flux Density plot of Thin solenoid coil

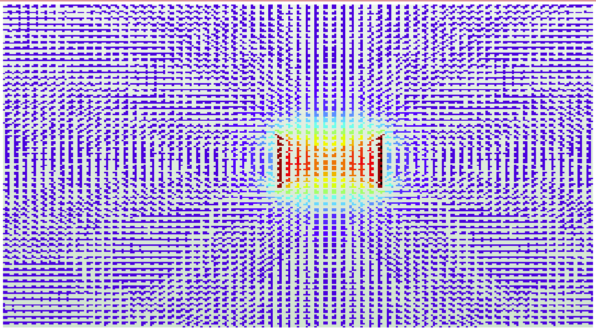

Figure 4 : Vector plot of Thin solenoid coil

Table 1: Compare Result of thin solenoid coil

Theoretical Result Flux Density at Center (T)	**ANSYS Result Flux Density at Center (T)**	**IES Result Flux Density at Center (T)**
0.376991118	0.35243	0.375899

V. Conclusion

Put the extra Ampere turn at the end of solenoid so that uniform magnetic field getting in centre of solenoid .In Table 1 Comparison of magnetic file d at centre of solenoid give better result in IES software just simple modelling and meshing of coil.In ANSYS require accurate meshing and put boundary condition proper .so it can be achieve accurate result in ansys. Result is mismatching some where which is because of the inductance mismatch as well as discrete load data entry in ANSYS. Optimized result has been obtained with increasing the air volume for FEA analysis

References

[1] Francis C. Moon, "Magneto-Solid Mechanics", Jhon Wiley & Sons, New York, 1984, pp 21 – 50.

[2] D.Bruce Montgomery and Robert J. Weggel,"Solenoid Magnet Design", Robert E. Krieger Publishing Company, New York; 1980, pp.1 – 23.

[3] J.B.Solanki, "Design, Simulation And Experiment On Pulsed Electromagnetic Coil With Toroidal Shaped Single Turn Coil For Induced Current Analysis", 2015 IEEE International Conference on Engineering and Technology (ICETECH), 20th March 2015, Coimbatore, TN, India,pp. 822-826.

[4] "Applied Superconductivity" : Handbook on Devices and Applications by edited by Paul Seidel

[5] ANSYS is a trademark of SAS Inc. www.ansys.com".

[6] R. A. Rimmer, et al., "An RF Cavity for the NLC Damping Rings", PAC 2001 Proceedings, PaperMPPH064.

[7] N. Hartman, R. A. Rimmer.et al. "Electromagnetic, Thermal ,And Structural Analysis Of Rfcavities Using Ansys" Proceedings of the 2001 Particle Accelerator Conference, Chicago.

[8] Maslen,E. 1999.Magnetic Bearings, Charlottesville, Virginia, USA, (personal note)

https://www.integratedsoft.com/papers/techdocs/tech_8mx.pdf.