Electromagnetic Analysis of Flat Spiral Coils Fed By a Current Pulse at Medium Frequency

O. Maloberti[1], P. Sansen[1], O. Mansouri[1], D. Jouaffre[2], D. Haye[2]

[1]ESIEE Amiens, France
[2]PFT Innovaltech, France

Abstract

Cylindrical single or multi-turns coils and Spiral Flat multi turn coils are used in pulsed magnetic technologies for which both magneto-harmonic and transient magnetic analysis are required. The first are mainly used for tubular geometries and the second are preferred for sufficiently thin discoid geometries like washers, plates and discs. Flat coils can be associated to a thicker intermediate plate used as a launcher that will push the part to deform against a matrix. Cylindrical single-turn coils have already been studied in [1]. Now, we suggest studying one flat multi-turns coil example made of height turns, an optional conducting launcher and an upper thin discoid plate supposed to be deformed. The aim of this study is to evaluate the accuracy and reliability of an approximate 2D axi-symetrical numerical model by comparing with references like measurements, 3D calculations or theory in order then to build an approximate but fast and reliable numerical or/and analytical solution that might ease the coupling with electrical, mechanical and thermal physics.
In this work we propose to:
- First introduce the 3D model and the approximate 2D axi-symetrical model in COMSOL Multiphysics®: definition of the symmetries, sources, the materials, the limit conditions and the mesh
- Secondly, introduce and perform magneto-harmonic computations:
o Give the governing physical equations and formulation
o Draw the potential, flux, current and Lorentz force density profiles
o Extract some needed information on the coil, such as the equivalent resistance, inductance and coefficient of force that acts onto the washer, the plate or the disc.
- Thirdly, introduce and perform transient magnetic computations
o Give the governing physical equations and formulation
o Draw the potential, flux, current and Lorentz force density profiles,
o Analysis of the relationship between the current pulse, the voltage pulse and the Lorentz forces as a function of time.
- Finally, introduce and perform the transient coupling with an electrical circuit
o Introduce the electrical circuit and the coupling principles
o Compare the current and voltage pulses with measurements for several conditions
References
[1] O. Maloberti, O. Mansouri, D. Jouaffre, D. Haye, "Harmonic and Transient Magnetic analysis of Single Turn Coils fed by a Current Pulse at Medium Frequency", COMSOL Conference 2015, 14-16 october 2015, Grenoble.

[2] A. El-Azab, M. Garnich, A. Kapoor, "Modeling of the electromagnetic forming of sheet metals: state-of-the-art and future needs", ELSEVIER, Journal of Materials Processing Technology 142 (2003) 744-754.
[3] S. Pasca et al., "Transient phenomena in electromagnetic forming processes", International Scientific Colloquium, Modelling for electromagnetic processing, Hannover, October 27-29, 2008, pp. 315-320.
[4] Zhipeng Lai et al., "The electromagnetic flanging of a large-scale sheet workpiece", IEEE Transactions on applied superconductivity, vol. 24, no. 3, June 2014.
[5] M. Ahmed et al., "Alternative flat coil design for electromagnetic forming using FEM", Transactions of non-ferrous metals society of china, vol. 21(2011), pp. 618-625.
[6] E. Paese et al., "Mathematical modeling of an electromagnetic forming system with flat spiral coils as actuator", 4th International Conference on High Speed Forming - 2010, pp. 219-228.
[7] E. Paese et al., "Simplified Mathematical Modeling for an Electromagnetic Forming System, with Flat Spiral Coil as Actuator", J. of the Braz. Soc. of Mech. Sci. & Eng., Vol. XXXIII, No. 3, July-September 2011, pp. 324-331.
[8] H. A. Ghali, H. A. Rahman, "Understanding Mutual Inductance using COMSOL Multiphysics", Excerpt from the Proceedings of the COMSOL Conference 2009 Milan.
[9] S. Babic, C. Akyel, "Improvement in Calculation of the Self- and Mutual Inductance of Thin-Wall Solenoids and Disk Coils", IEEE TRANSACTIONS ON MAGNETICS, VOL. 36, NO. 4, JULY 2000.
[10] J. Bednarczyk, "Analytical determining of forces and pressures during electrodynamical metal forming", International Carpathian Control Conference ICCC' 2002, May 27-30, 2002, pp. 187-192.

Figures used in the abstract

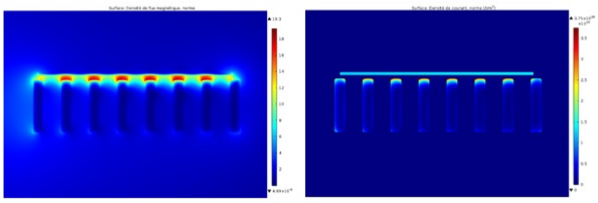

Figure 1: Magnitude of the flux density (left) and the current density (right) @ 6 kHz.