Vibroacoustic Models of Air-Core Reactors

Thiago A. Fiorentin

Universidade Federal de Santa Catarina — UFSC, Mobility Engineering Center, 89218-035 — Joinville — SC, Brazil

Leonardo Ferreira Lopes

Universidade do Oeste de Santa Catarina — UNOESC, Technological Center, 89600-000 — Joaçaba — SC, Brazil

Olavo Mecias da Silva Junior and Arcanjo Lenzi

Universidade Federal de Santa Catarina — UFSC, Department of Mechanical Engineering, 88040-900 — Florianópolis — SC, Brazil

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The purpose of this paper is to provide an overview of the sound power radiation mechanism of air-core reactors and to describe the method that is used to calculate sound power by using the electrical load. Sound power radiation of an air-core reactor is related to the alternating current harmonics, the mechanical tension stiffness and, most importantly, the breathing mode resonance. An analytical model that is based on electrical loads and mechanical properties of the air-core reactor is developed to calculate radial and axial forces caused by the radial and axial magnetic induction fields. This study employs the hemispherical spreading theory, which is a simple and common method that is used to predict sound propagation. Additionally, a numerical model is proposed. In this, the excitation of the acoustic field that surrounds the reactor is introduced by considering the radial and axial displacements of the reactor's windings, as the windings are subjected to the action of the radial and axial electromagnetic forces. Finally, a comparison is presented between analytical and numerical models and it is observed that the models are correlated.

NOMENCLATURE

B	magnetic induction field
B_{radial}	radial magnetic induction field
B_{axial}	axial magnetic induction field
$B_{avrg,z}$	average magnetic induction field at z direction
$B_{avrg,x}$	average magnetic induction field at x direction
c_0	speed of sound in air
dl	infinitesimal element
E	equivalent Young's modulus
E_{fib}	Young's modulus of the fiberglass
e	thickness of the winding
e_{fib}	thickness of the fiberglass
e_{iso}	thickness of the insulation
F	electromagnetic force
$F_{avrg,x}$	average force at x direction
F_{axial}	axial electromagnetic force
F_{radial}	radial electromagnetic force
$F_{Z,avrg}$	average force at z direction
f	frequency of the current
G_{xy}	shear modulus at plane xy
G_{xz}	shear modulus at plane xz
G_{yz}	shear modulus at plane yz
H	average height of the winding
h_{ws}	height of the reactor without the spiders
I_{eff}	effective current
i	electrical current
K	stiffness of a mechanical system
K_{eq}	equivalent stiffness
K_{fib1}	stiffness of fiber layer 1
K_{fib2}	stiffness of fiber layer 2
l	height of the material
l_{ms}	perimeter of measurement surface
$\overline{L_P}$	average sound pressure
L_P	sound pressure level
L_W	sound power level
M	mass of the winding
N	number of turns per unit of length
nbr	total average number of turns in the winding
p	sound pressure
p_0	reference sound pressure
R	average radius of the winding
R_e	external radius of the winding
R_i	internal radius of the winding
r	distance point to source
r_{sr}	distance source-receiver
S	surface of contact between two materials
S_m	surface area of measurement
S_W	sound radiating surface
S_0	reference area
t	time
ν_{rad}	average radial speed of the winding
W	radiated sound power
W_0	reference power