AC Analysis of a Three-Phase Transformer

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1. Introduction
2. Model View
3. Materials
4. Load & Restraint Information
5. Coils Information
6. Study Properties
7. Results Table
8. Magnetic Flux Density Results
9. Magnetic Field Intensity Results
10. Applied Current Density Results
11. Eddy Current Density Results
12. Force Distribution Results
13. Temperature Results
14. Temperature Gradient Results
15. Heat Flux Results
16. Appendix

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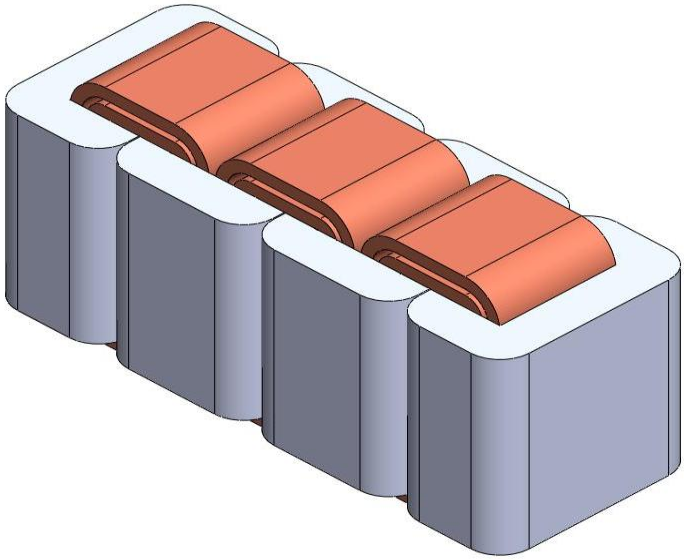
1. Introduction

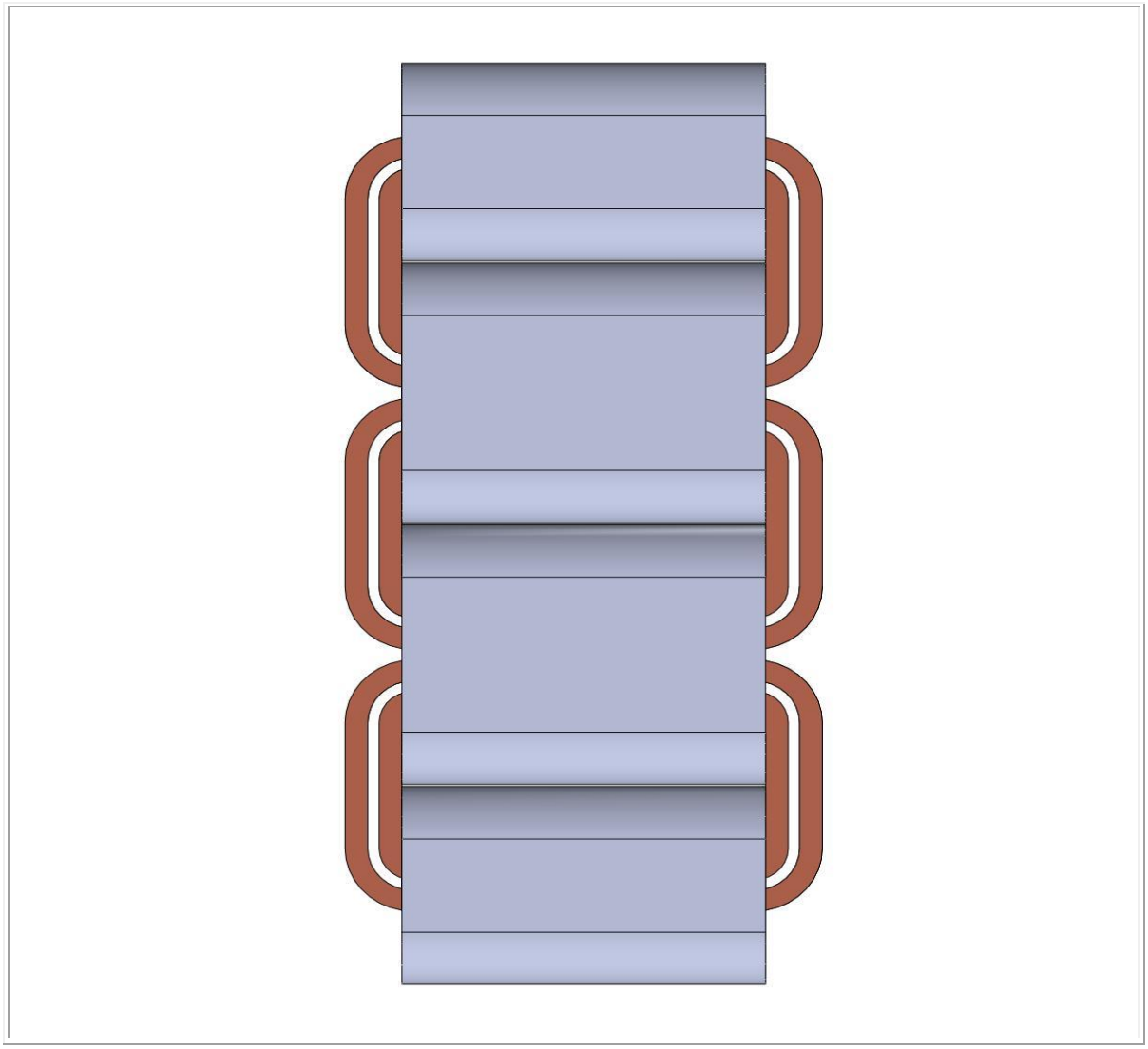
A three-phase transofmer is analyzed using the AC magnetic module of EMS. The transformer consists of three feeding copper coils, and three secondary coils. The core is composed of mild steel. The results are recorded in the EMS report, and include the magnetic flux density, the eddy current density. A steady-state thermal analysis can also be couple with the magnetic analysis, yielding the temperature, and the heat flux.

2. Model View

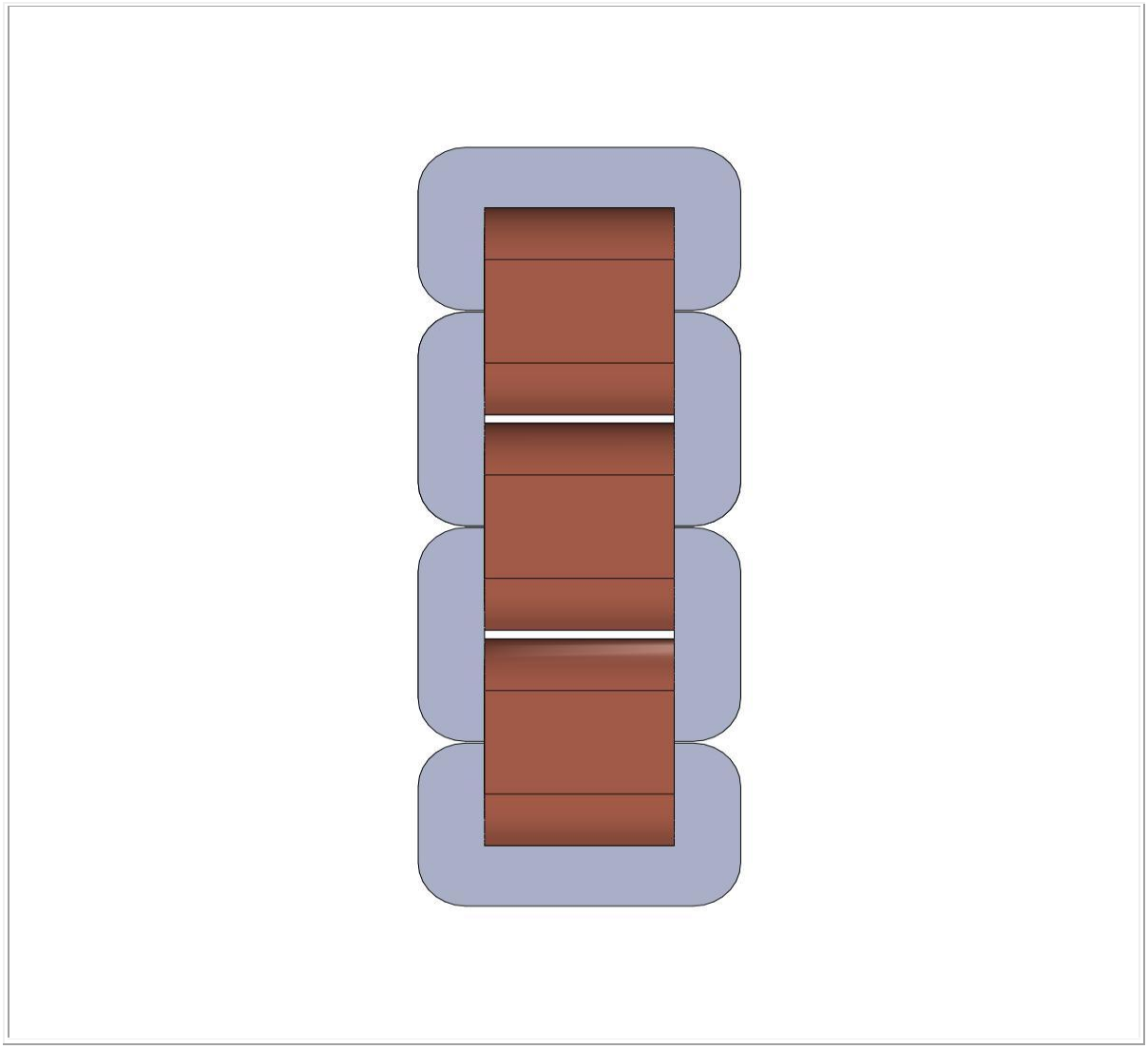
Transformer_Isometric View



Transformer_Front View



Transformer_Top View



Transformer_Current View (Mesh)

3. Materials

Note: R.P. stands for Relative Permeability

Nbr.	Part Name	Material Name	Permeability Type
1	Core-1-Body 1 (Fillet19)	Mild Steel	Isotropic
2	Core-1-Body 2 (Fillet28)	Mild Steel	Isotropic
3	Core-1-Body 3 (Fillet29)	Mild Steel	Isotropic
4	Core-1-Body 4 (Fillet32)	Mild Steel	Isotropic
5	Inner Air-1-Body 1 (Cavity1[1])	Air	Isotropic

6	Inner Air-1-Body 2 (Cavity1[2])	Air	Isotropic
7	Inner Air-1-Body 3 (Cavity1[3])	Air	Isotropic
8	Inner Air-1-Body 4 (Cavity1[4])	Air	Isotropic
9	Inner Air-1-Body 5 (Cavity1[5])	Air	Isotropic
10	Inner Air-1-Body 6 (Cavity1[6])	Air	Isotropic
11	Inner Air-1-Body 7 (Cavity1[7])	Air	Isotropic
12	Inner Air-1-Body 8 (Cavity1[8])	Air	Isotropic
13	Inner Coil 1-1-Body 1 (Split1[1])	Copper	Isotropic
14	Inner Coil 1-1-Body 2 (Split1[2])	Copper	Isotropic
15	Inner Coil 2-1-Body 1 (Split1[1])	Copper	Isotropic
16	Inner Coil 2-1-Body 2 (Split1[2])	Copper	Isotropic
17	Inner Coil 3-1-Body 1 (Split1[1])	Copper	Isotropic
18	Inner Coil 3-1-Body 2 (Split1[2])	Copper	Isotropic
19	Outer Air-1-Body 1 (Cavity1)	Air	Isotropic
20	Outer Coil 1-1-Body 1 (Split1[1])	Copper	Isotropic
21	Outer Coil 1-1-Body 2 (Split1[2])	Copper	Isotropic
22	Outer Coil 2-1-Body 1 (Split1[1])	Copper	Isotropic
23	Outer Coil 2-1-Body 2 (Split1[2])	Copper	Isotropic
24	Outer Coil 3-1-Body 1 (Split1[1])	Copper	Isotropic
25	Outer Coil 3-1-Body 2 (Split1[2])	Copper	Isotropic

4. Load & Restraint Information

Thermal Loads

Nbr.	Name	Convection Coefficient (W/(m^2.K))	Ambient Temperature (Kelvin)	Selected Faces	Selected Components
1	Convection - 1	1.000e+001	3.000e+002	26	None
2	Convection - 2	1.000e+001	3.000e+002	18	None

5. Coils Information

Coils

Nbr.	Name	Nbr.Of Turns	Magnitude	Phase	Components & Bodies
1	Wound Coil - 1	300	1.000000e+001	0.0000e+000 deg	Split1[1] Split1[2]
2	Wound Coil - 2	300	1.000000e+001	2.0944e+000 deg	Split1[1] Split1[2]
3	Wound Coil - 3	300	1.000000e+001	4.1888e+000 deg	Split1[1] Split1[2]
4	Wound Coil - 4	200	0.000000e+000	0.0000e+000 deg	Split1[1] Split1[2]
5	Wound Coil - 5	200	0.000000e+000	0.0000e+000 deg	Split1[1] Split1[2]
6	Wound Coil - 6	200	0.000000e+000	0.0000e+000 deg	Split1[1] Split1[2]

6. Study Properties

Mesh Information

Nbr.Of Nodes	Nbr.Of Elements	Element Size (m)	Tolerance (m)
58962	352861	0.400000	0.001000

Mesh Controls information

Nbr.	Name	Mesh Size	Size Unit	Components & Bodies	Selected Faces
1	MeshControl - 1	20.000000	mm	Inner Coil 1-1 Outer Coil 1-1 Inner Coil 2-1 Outer Coil 2-1 Inner Coil 3-1 Outer Coil 3-1	
2	MeshControl - 2	40.000000	mm	Core-1	
3	MeshControl - 3	10.000000	mm	Inner Air-1	

Solver information

Frequency (Hz)	Compute inductance
6.000000e+001	YES

7. Results Table

Inductance Results

Inductance (H)	Wound Coil - 1	Wound Coil - 2	Wound Coil - 3	Wound Coil - 4	Wound Coil - 5	Wound Coil - 6
Wound Coil - 1	1.813024e-002	-4.389690e-004	8.203442e-004	-1.159012e-002	3.825709e-004	-1.173252e-003
Wound Coil - 2	-4.389690e-004	8.203442e-004	-1.159012e-002	3.825709e-004	-1.173252e-003	3.632962e-004
Wound Coil - 3	8.203442e-004	-1.159012e-002	3.825709e-004	-1.173252e-003	3.632962e-004	-1.170826e-002
Wound Coil - 4	-1.159012e-002	3.825709e-004	-1.173252e-003	3.632962e-004	-1.170826e-002	1.622385e-003
Wound Coil - 5	3.825709e-004	-1.173252e-003	3.632962e-004	-1.170826e-002	1.622385e-003	-2.460652e-004
Wound Coil - 6	-1.173252e-003	3.632962e-004	-1.170826e-002	1.622385e-003	-2.460652e-004	1.307743e-002

Flux Linkage Results

Coil Name	Flux Linkage (Wb)
Wound Coil - 1	1.851162e-001
Wound Coil - 2	1.685381e-001
Wound Coil - 3	1.858017e-001
Wound Coil - 4	-1.232121e-001
Wound Coil - 5	-1.028192e-001
Wound Coil - 6	-1.251822e-001

Induced Voltage Results

Coil Name	Induced Voltage (V)
Wound Coil - 1	6.978715e+001
Wound Coil - 2	6.353737e+001
Wound Coil - 3	7.004557e+001
Wound Coil - 4	-4.644985e+001
Wound Coil - 5	-3.876192e+001
Wound Coil - 6	-4.719257e+001

Part Power Results

Part Name	Power (W)
Inner Coil 1-1 - Body 2 (Split1[2])	1.027215e+002
Inner Coil 1-1 - Body 1 (Split1[1])	1.026992e+002
Core-1 - Body 2 (Fillet28)	1.007551e+002
Core-1 - Body 1 (Fillet19)	5.188549e+001
Core-1 - Body 3 (Fillet29)	1.005187e+002
Core-1 - Body 4 (Fillet32)	5.261732e+001
Outer Coil 3-1 - Body 2 (Split1[2])	0.000000e+000
Outer Coil 3-1 - Body 1 (Split1[1])	0.000000e+000
Inner Coil 3-1 - Body 2 (Split1[2])	1.026627e+002
Inner Coil 3-1 - Body 1 (Split1[1])	1.027090e+002
Outer Coil 2-1 - Body 2 (Split1[2])	0.000000e+000
Outer Coil 2-1 - Body 1 (Split1[1])	0.000000e+000
Inner Coil 2-1 - Body 1 (Split1[1])	1.027120e+002
Inner Coil 2-1 - Body 2 (Split1[2])	1.026968e+002
Outer Coil 1-1 - Body 2 (Split1[2])	0.000000e+000
Outer Coil 1-1 - Body 1 (Split1[1])	0.000000e+000
Outer Air-1 - Body 1 (Cavity1)	0.000000e+000
Inner Air-1 - Body 4 (Cavity1[4])	0.000000e+000
Inner Air-1 - Body 3 (Cavity1[3])	0.000000e+000

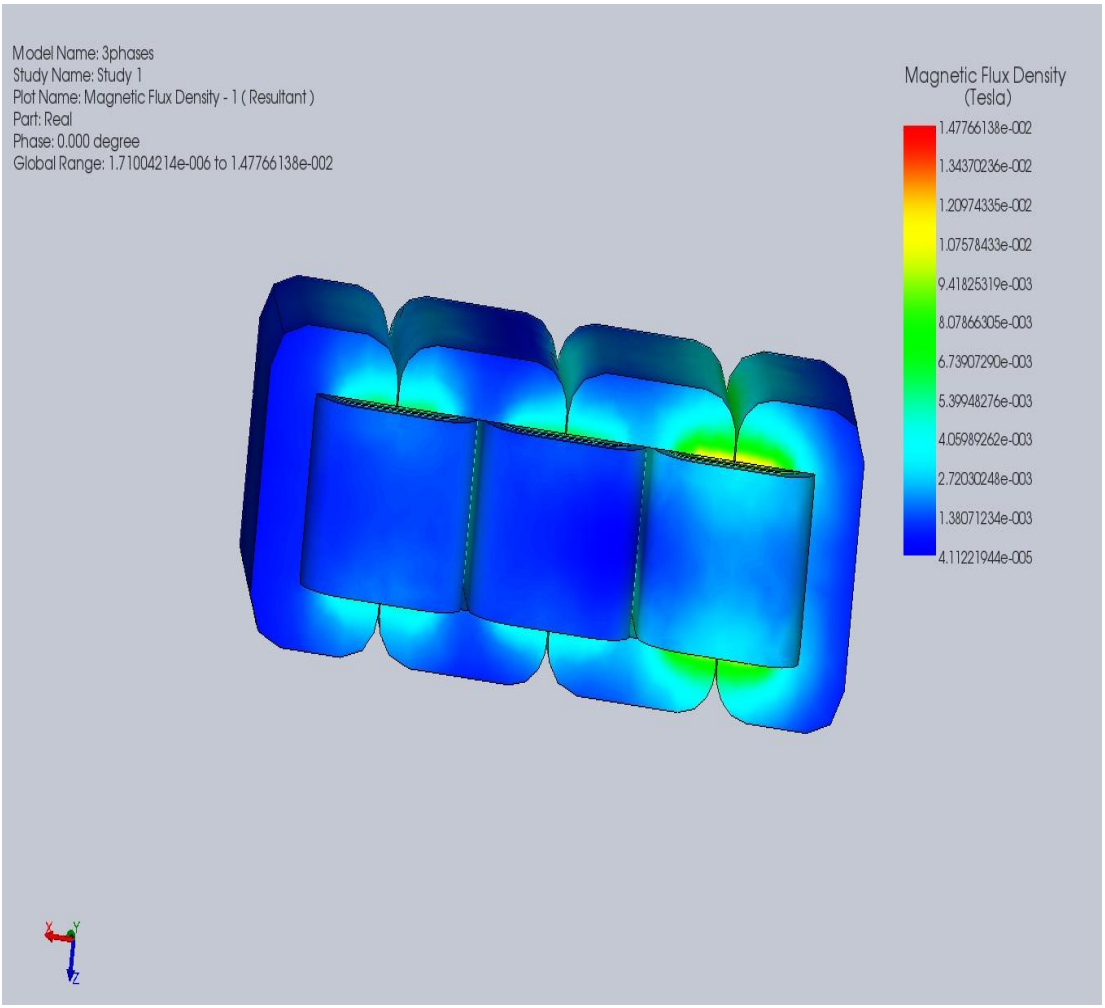
Inner Air-1 - Body 8 (Cavity1[8])	0.000000e+000
Inner Air-1 - Body 1 (Cavity1[1])	0.000000e+000
Inner Air-1 - Body 7 (Cavity1[7])	0.000000e+000
Inner Air-1 - Body 5 (Cavity1[5])	0.000000e+000
Inner Air-1 - Body 2 (Cavity1[2])	0.000000e+000
Inner Air-1 - Body 6 (Cavity1[6])	0.000000e+000

Energy Results

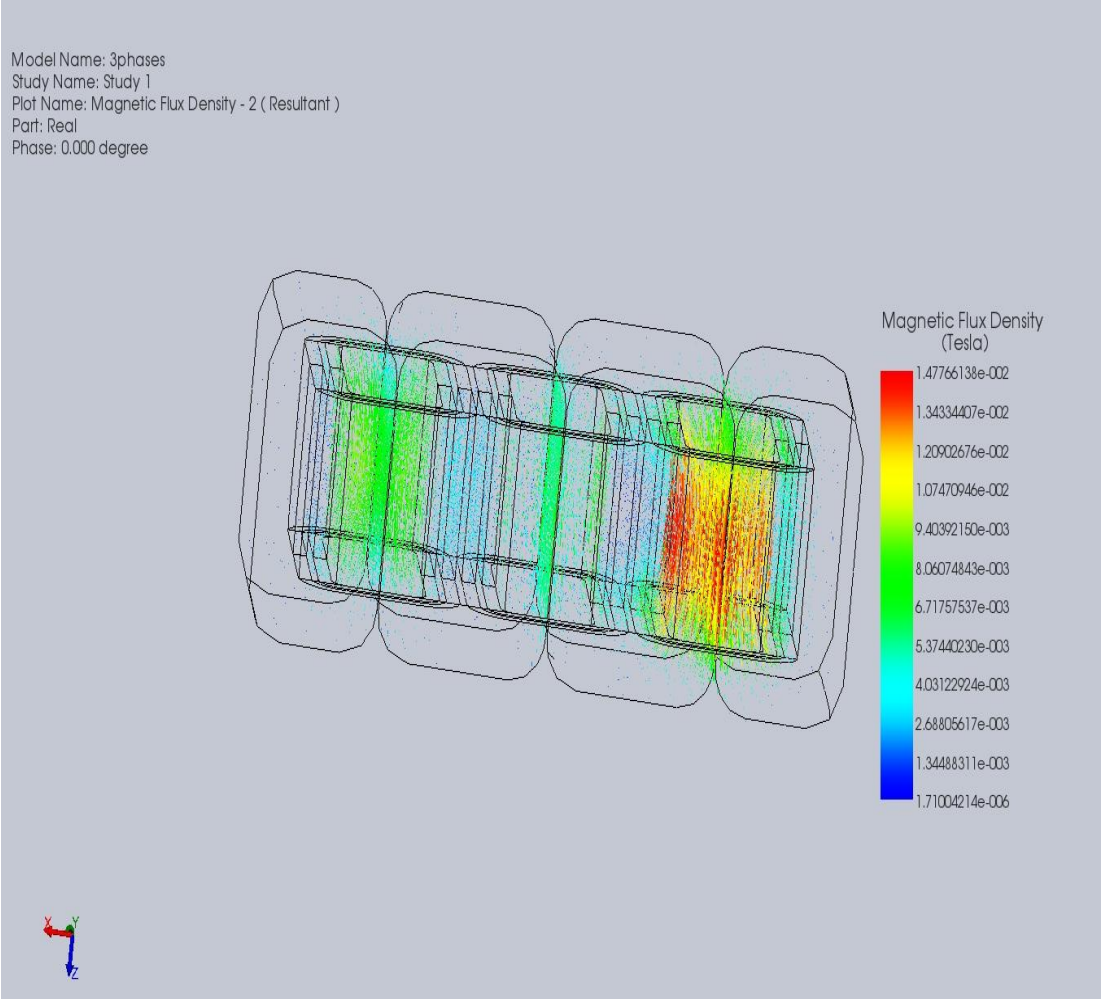
Inner Air-1 - Body 6 (Cavity1[6])	0.000000e+000	Energy (J)	Co-Energy (J)
2.704045e+000	0.000000e+000		

8. Magnetic Flux Density Results

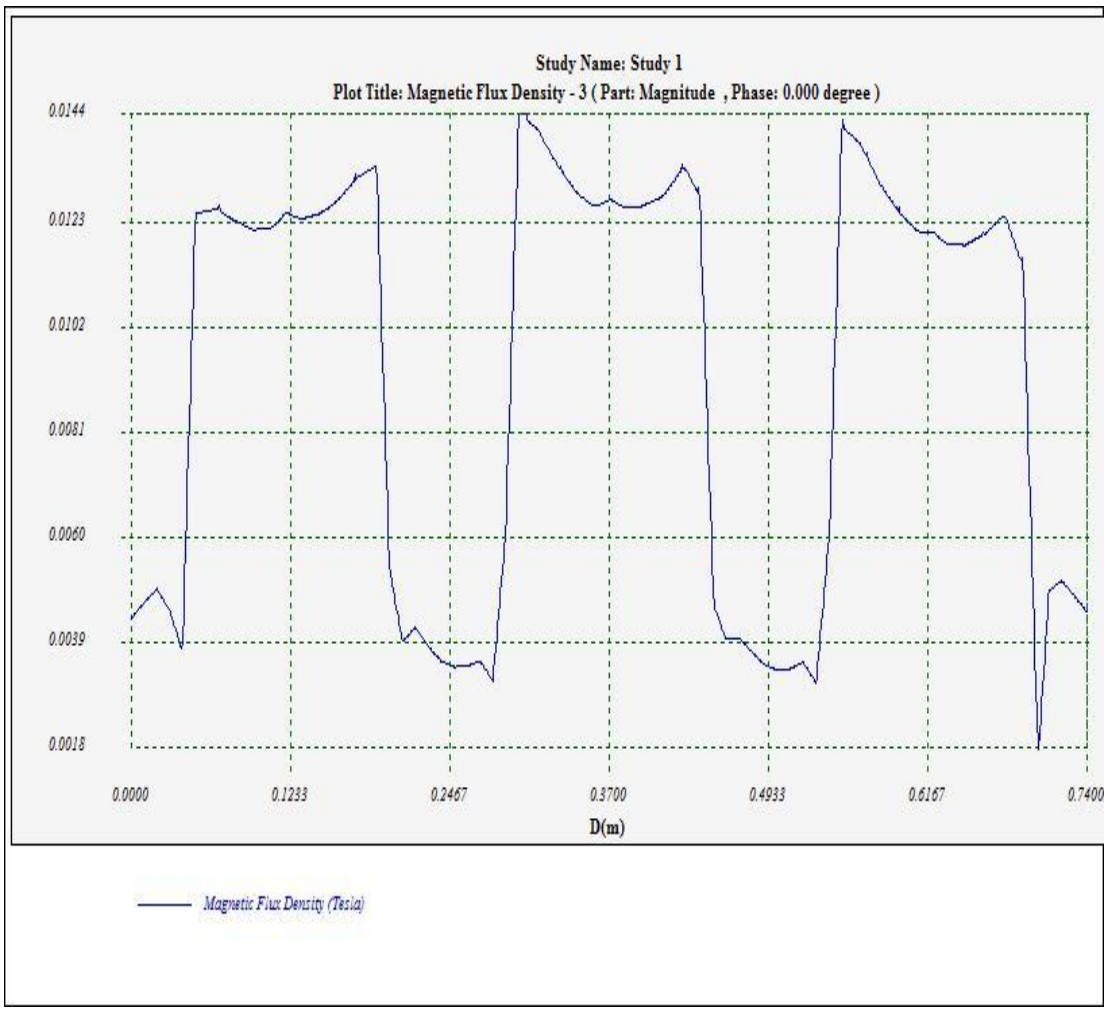
Magnetic Flux Density - 1



Magnetic Flux Density - 2

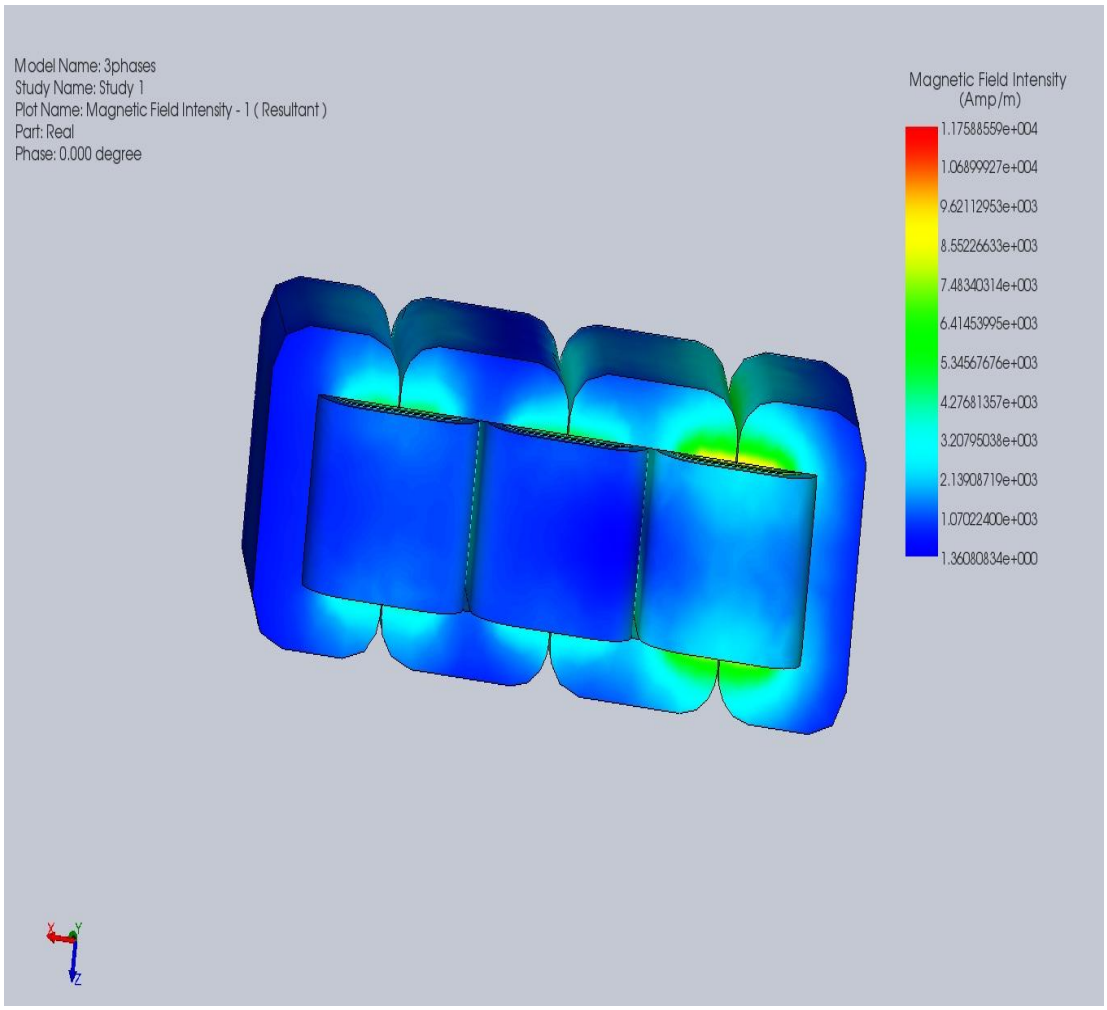


Magnetic Flux Density - 3

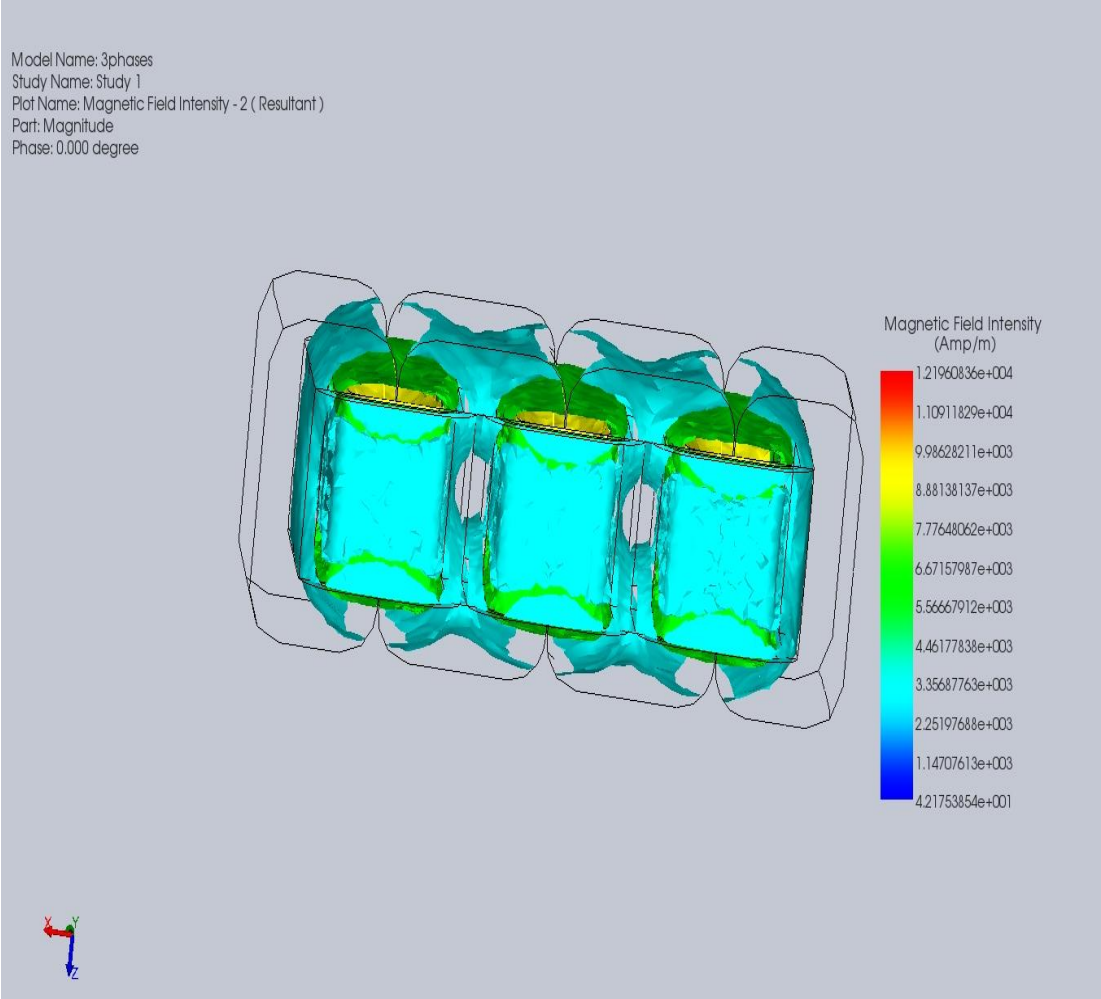


9. Magnetic Field Intensity Results

Magnetic Field Intensity - 1

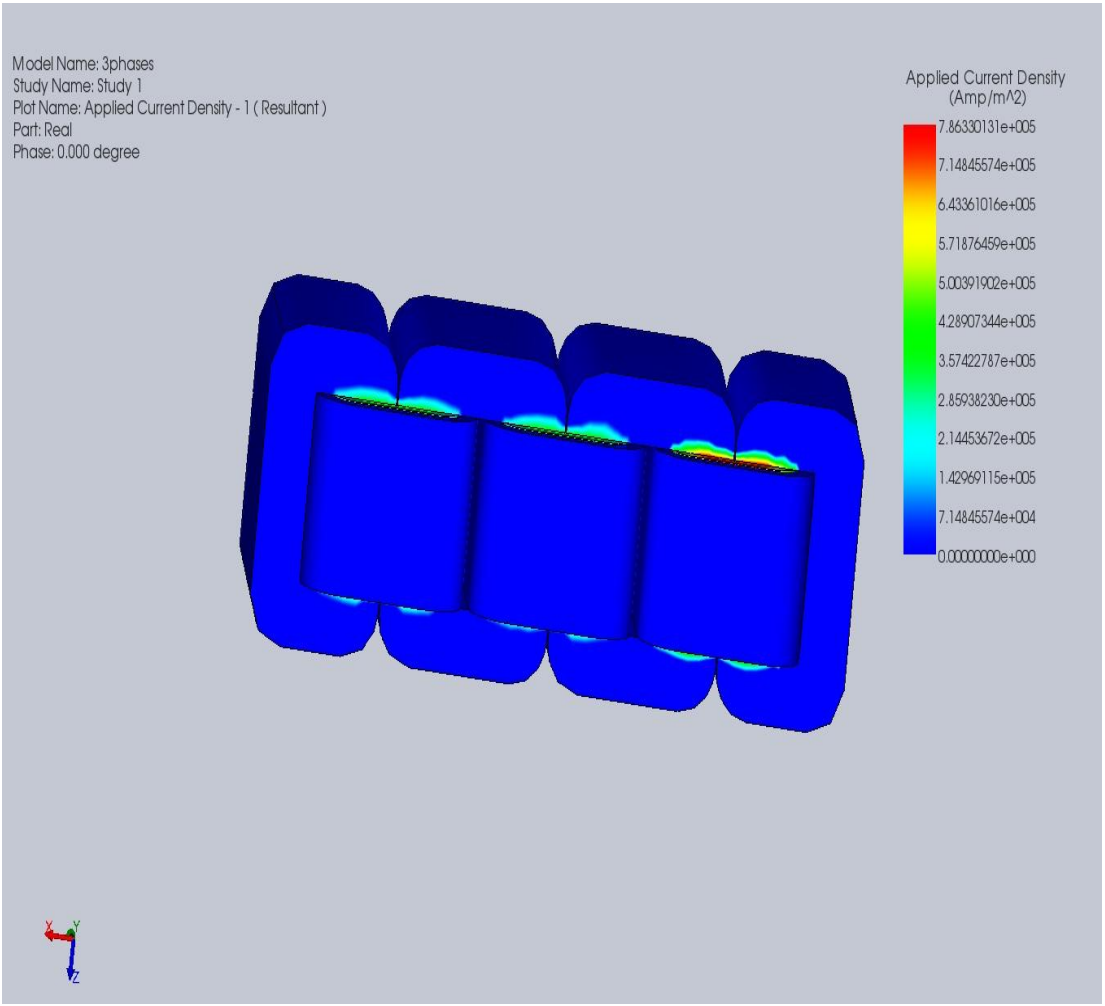


Magnetic Field Intensity - 2

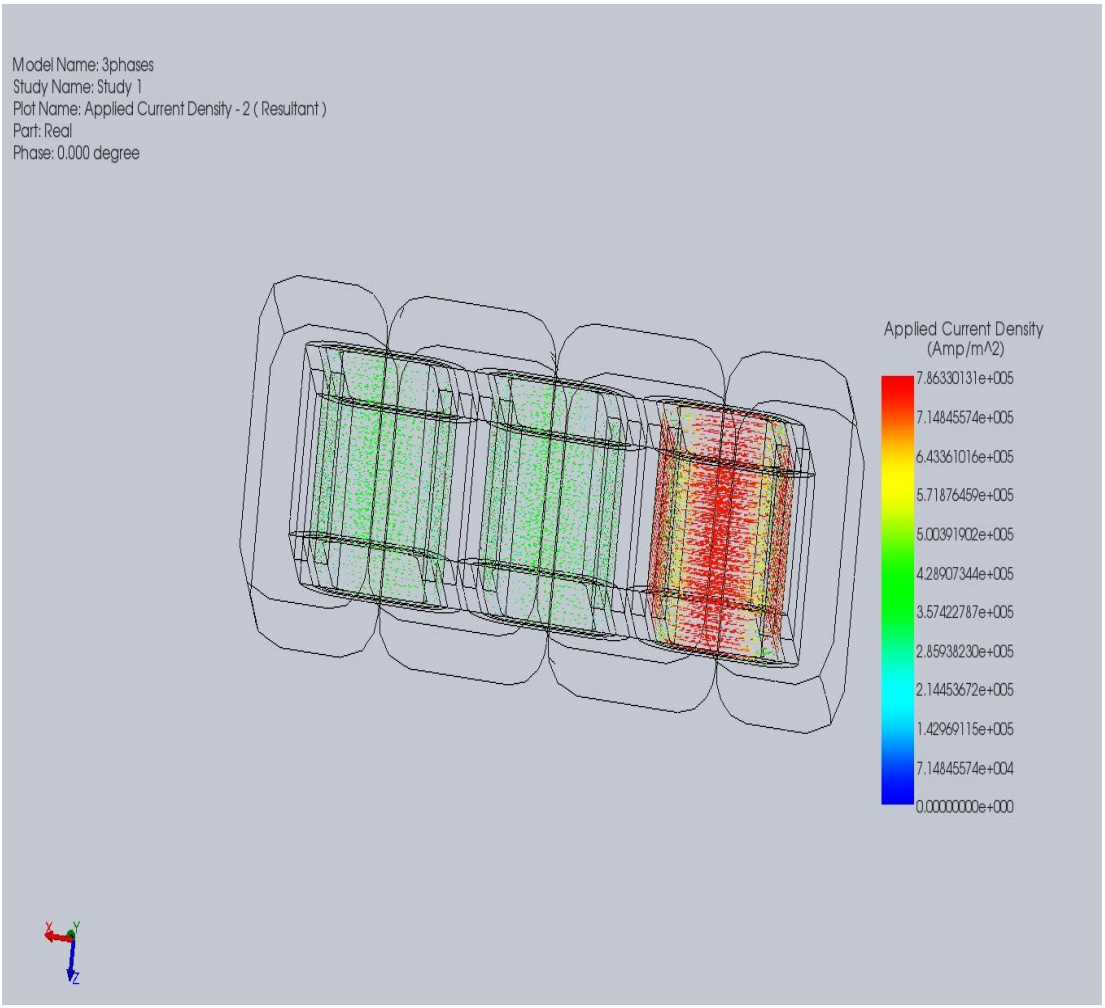


10. Applied Current Density Results

Applied Current Density - 1

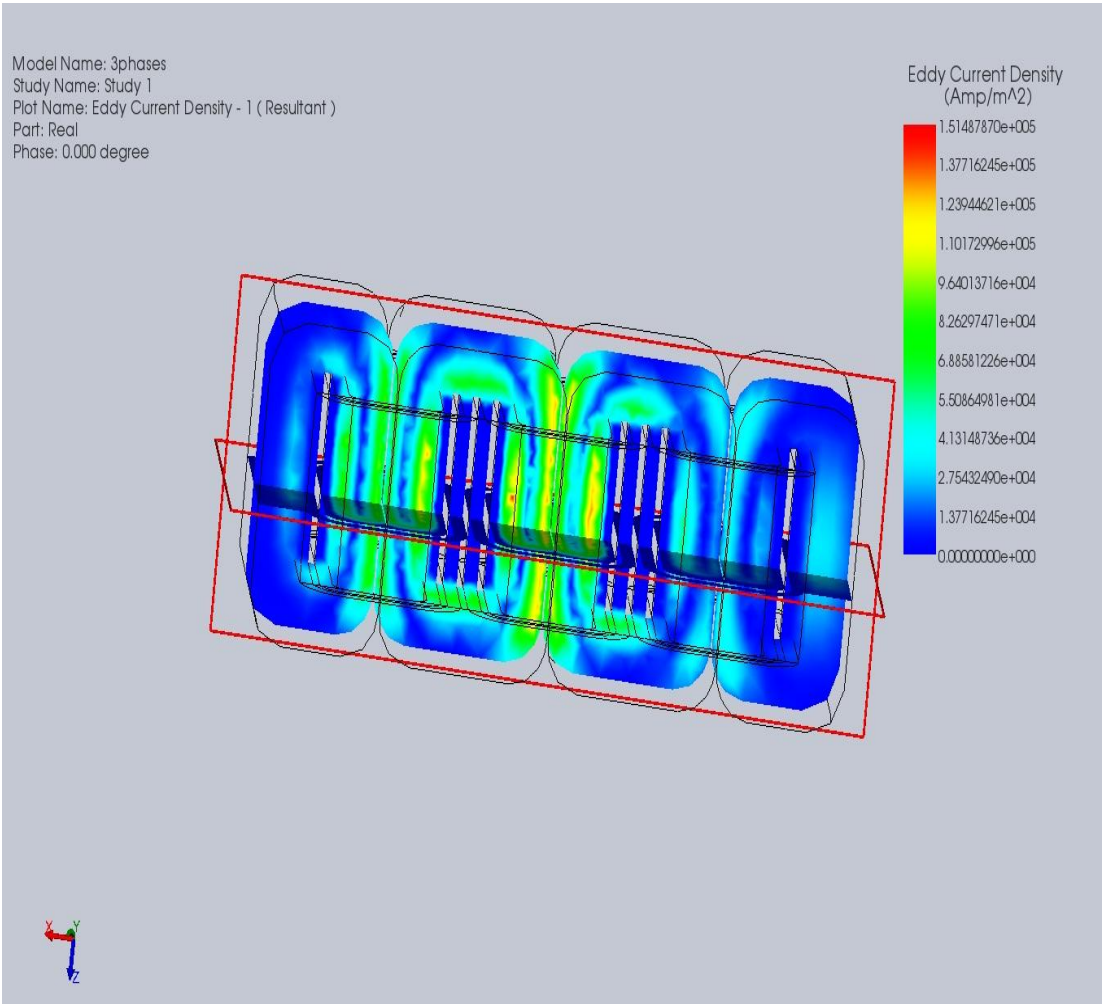


Applied Current Density - 2

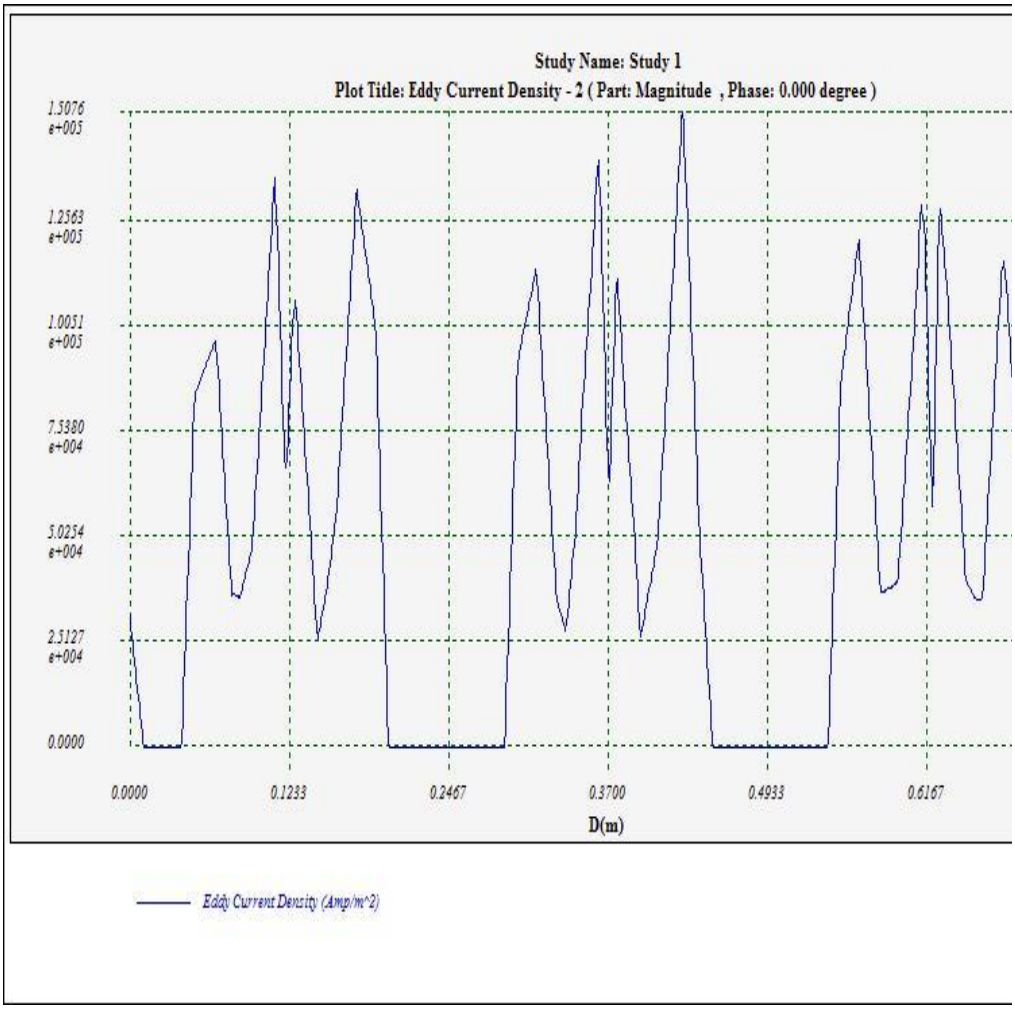


11. Eddy Current Density Results

Eddy Current Density - 1

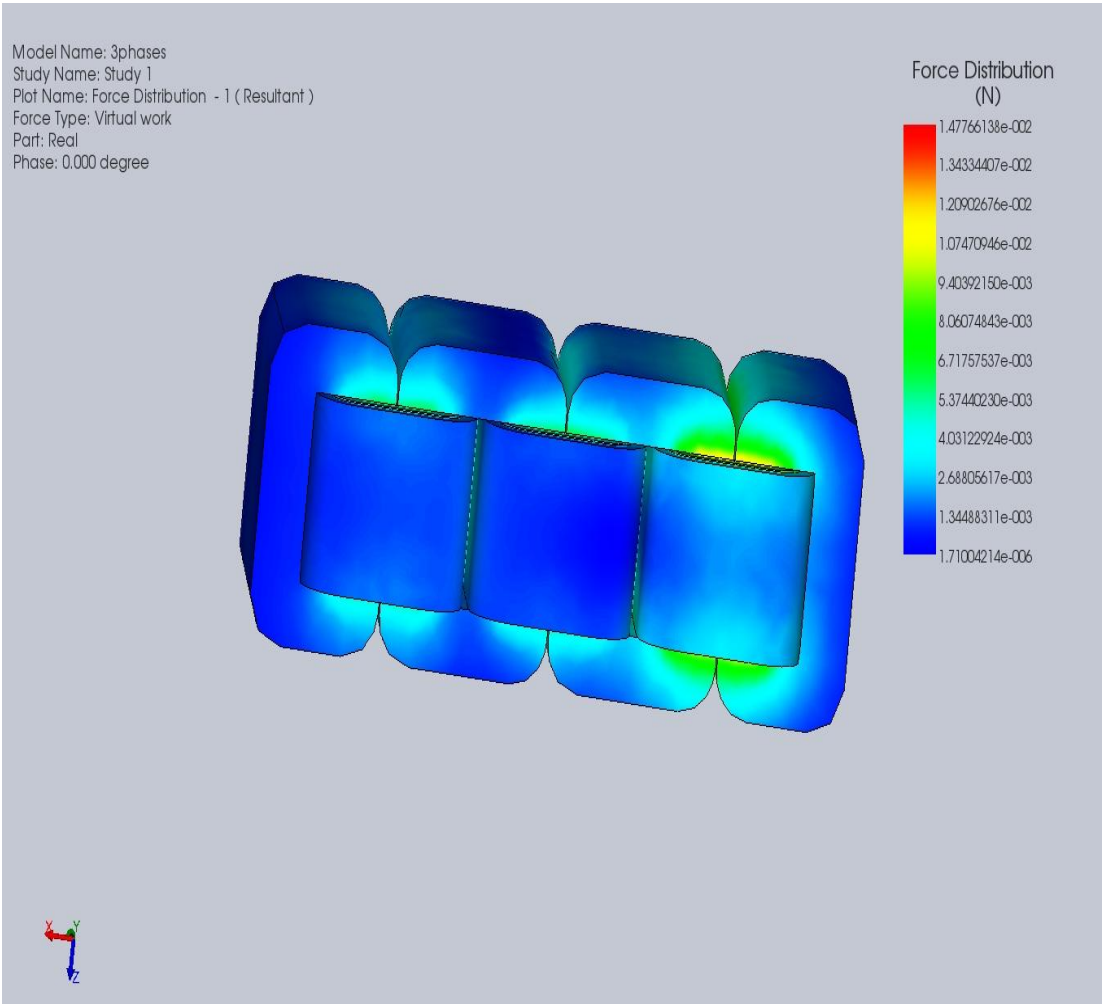


Eddy Current Density - 2



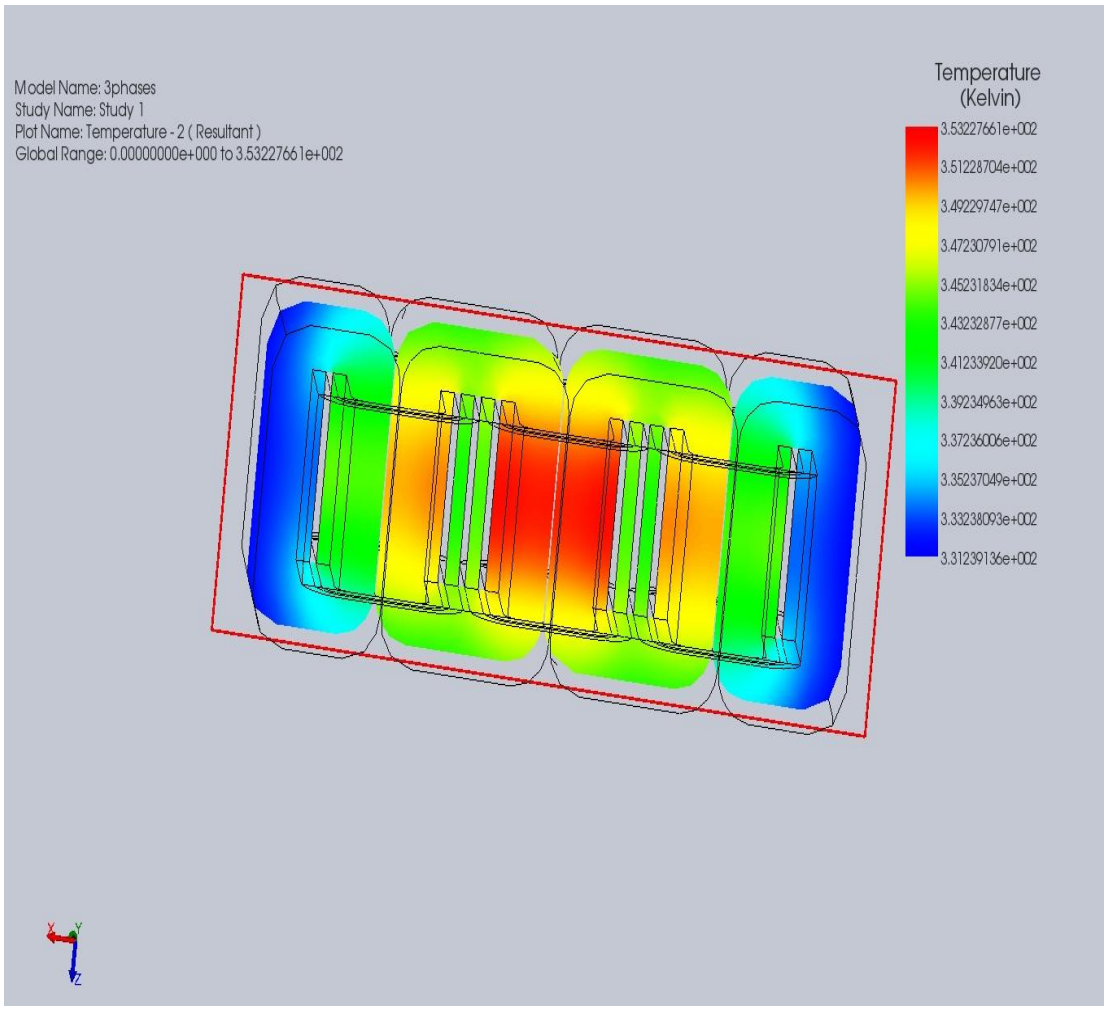
12. Force Distribution Results

Force Distribution - 1

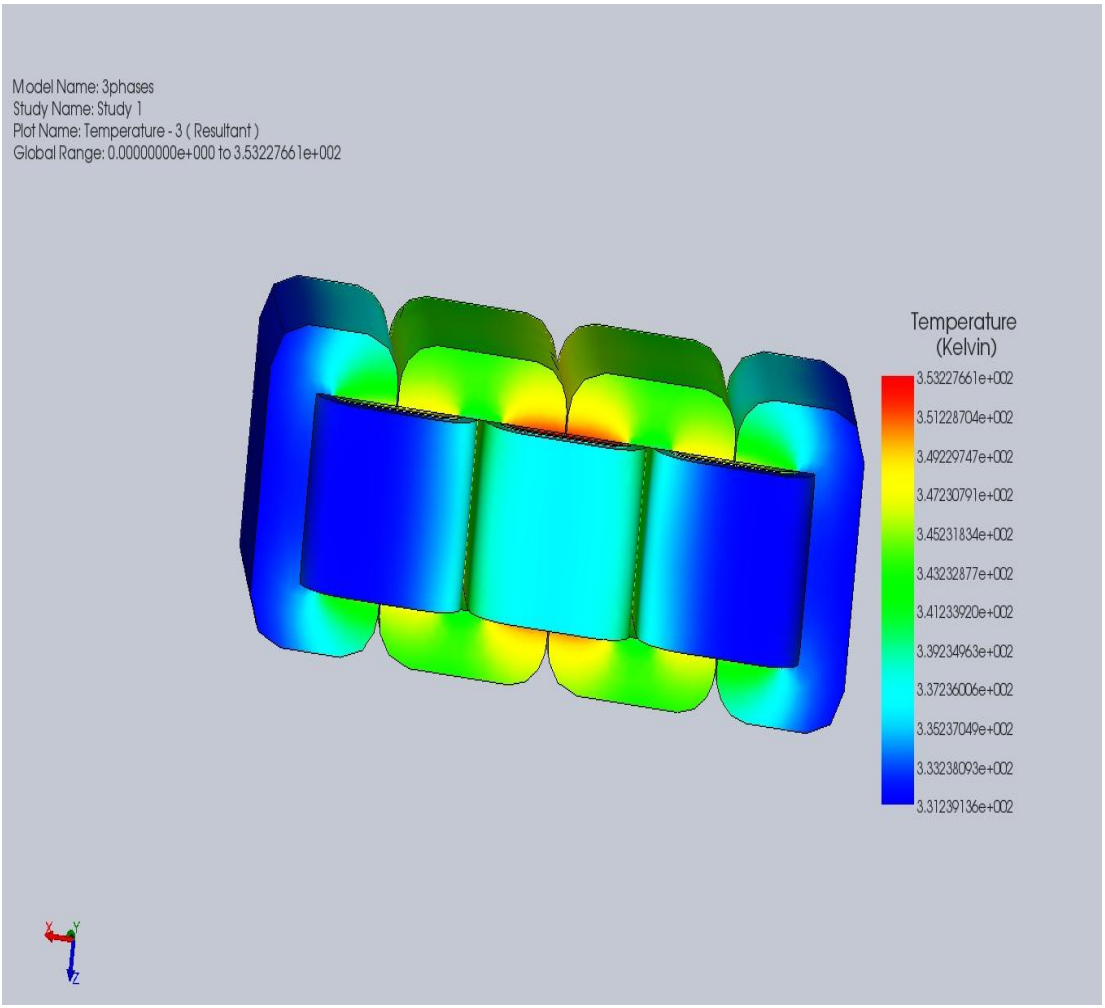


13. Temperature Results

Temperature - 2

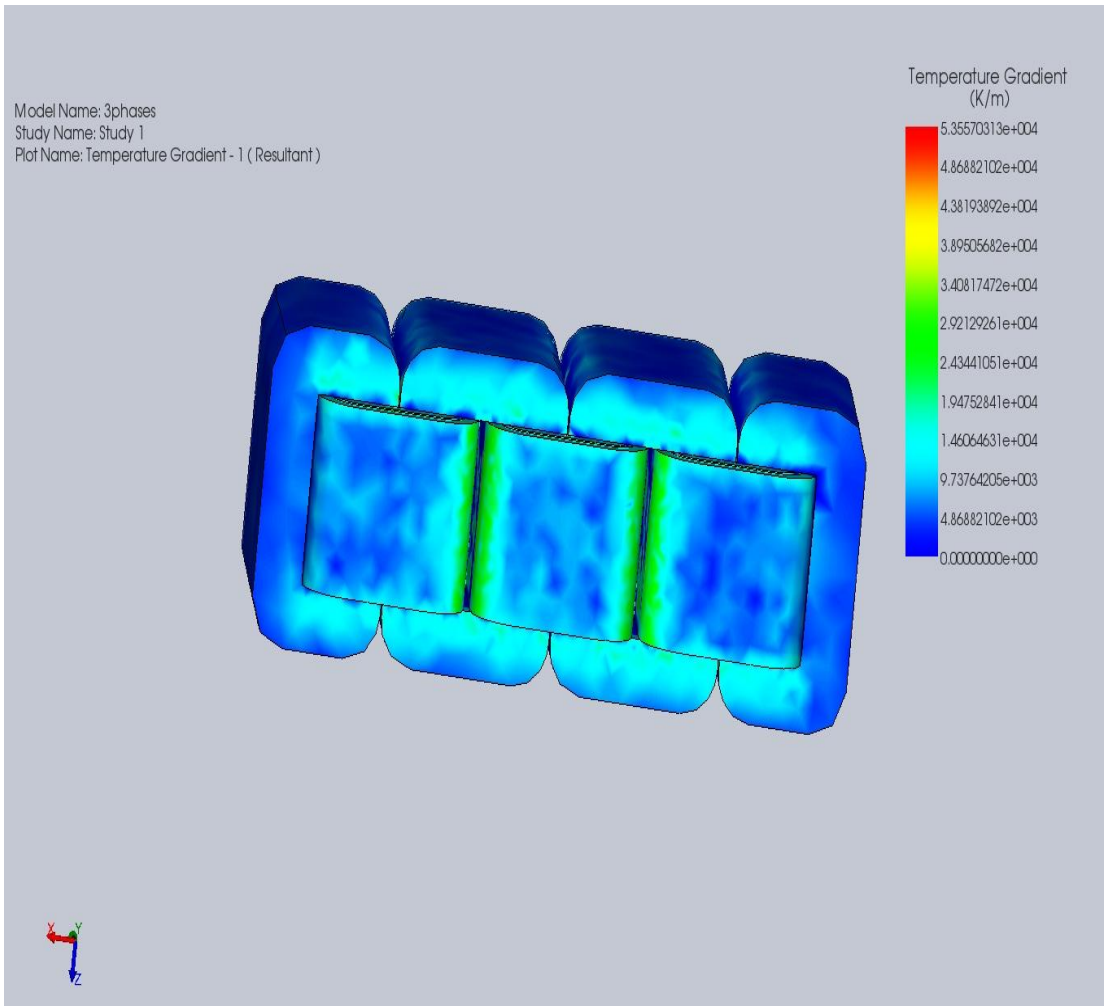


Temperature - 3



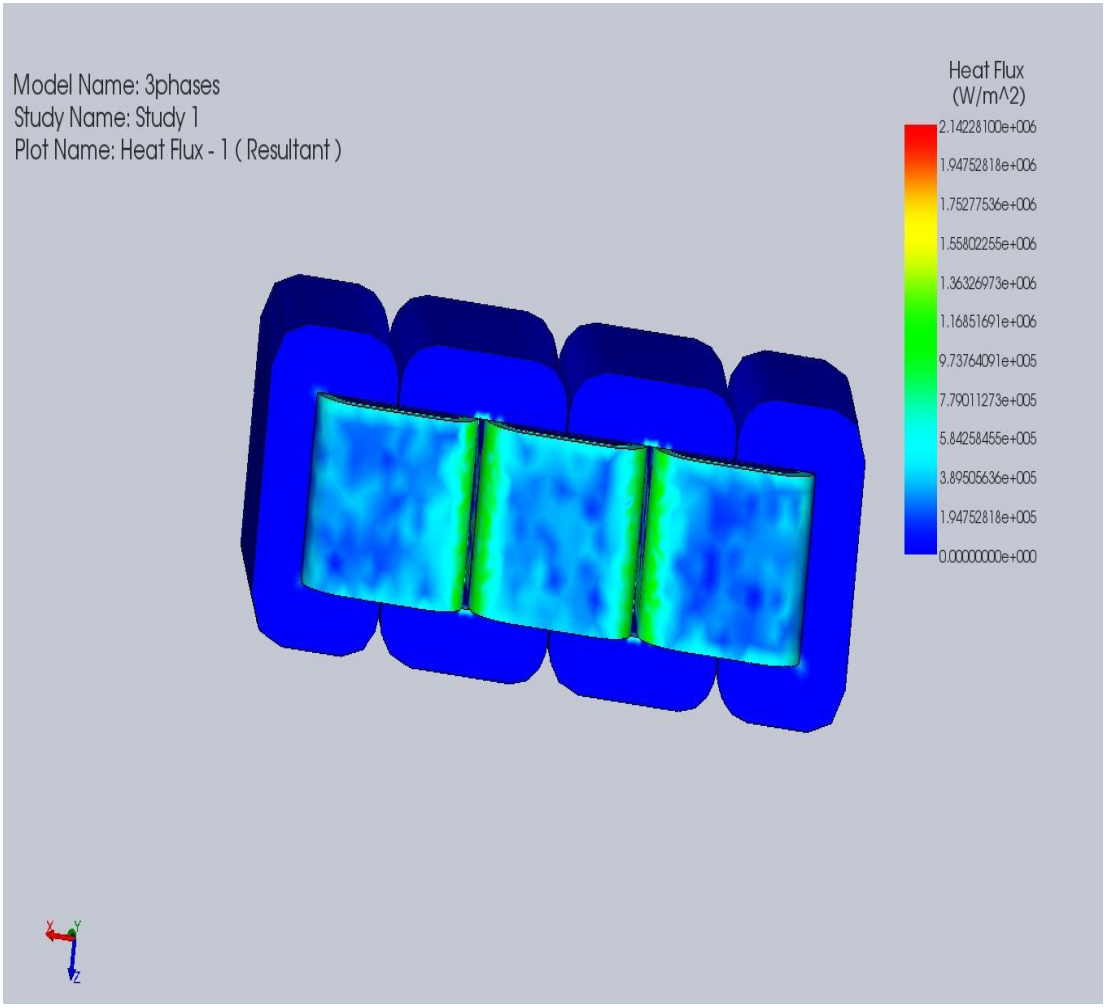
14. Temperature Gradient Results

Temperature Gradient - 1



15. Heat Flux Results

Heat Flux - 1



16. Appendix

Material Name: Mild Steel

Permeability Type: Isotropic

Note: R.P. stands for Relative Permeability

R.P.	Conductivity(Mho/m)	Permanent Magnet	Thermal Conductivity (W/m.K)
0.000e+000	1.100e+006	NO	1.000e+001

Material Name: Air

Permeability Type: Isotropic

Note: R.P. stands for Relative Permeability

R.P.	Conductivity(Mho/m)	Permanent Magnet	Thermal Conductivity (W/m.K)
1.000e+000	0.000e+000	NO	0.000e+000

Material Name: Copper

Permeability Type: Isotropic

Note: R.P. stands for Relative Permeability

R.P.	Conductivity(Mho/m)	Permanent Magnet	Thermal Conductivity (W/m.K)
1.000e+000	1.000e+007	NO	4.000e+001