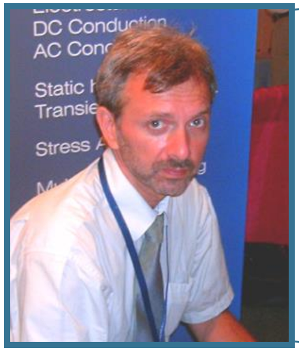
Iron core loss calculation with QuickField

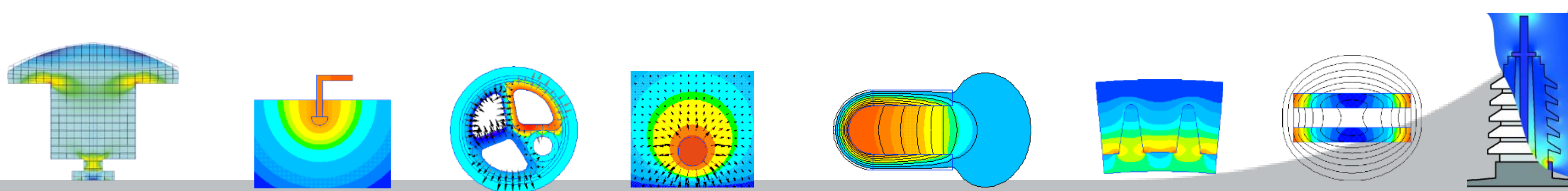


Vladimir Podnos,
Director of Marketing and Support,
Tera Analysis Ltd.

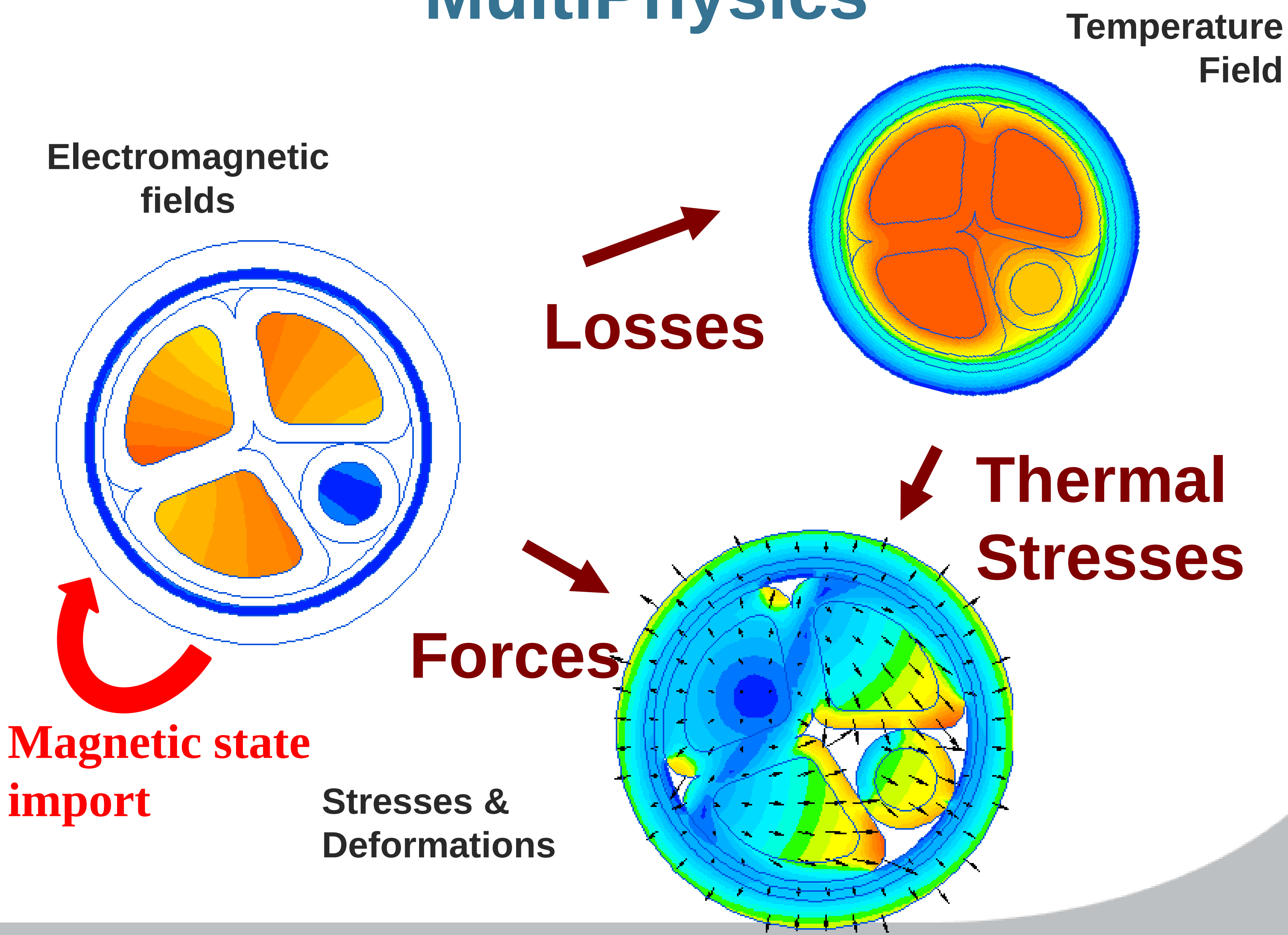
Alexander Lyubimtsev
Support Engineer
Tera Analysis Ltd.

QuickField Analysis Options

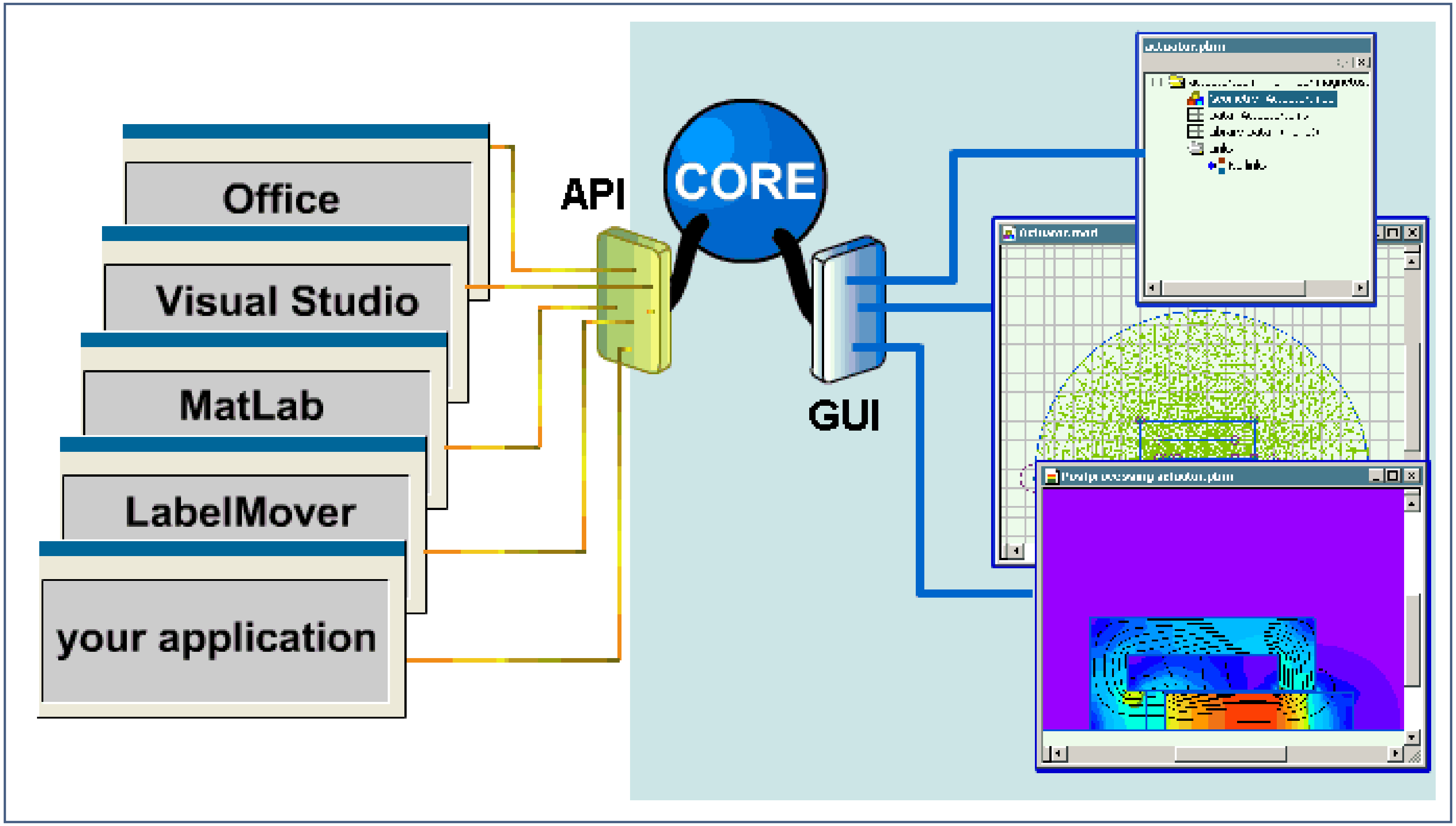
Magnetic analysis suite	
Magnetic Problems	Magnetostatics
	AC Magnetics
	Transient Magnetic
Electric analysis suite	
Electric Problems	Electrostatics (2D,3D) and DC Conduction
	AC Conduction
	Transient Electric field
Thermostructural analysis suite	
Thermal and mechanical problems	Steady-State Heat transfer
	Transient Heat transfer
	Stress analysis



MultiPhysics



Open object interface



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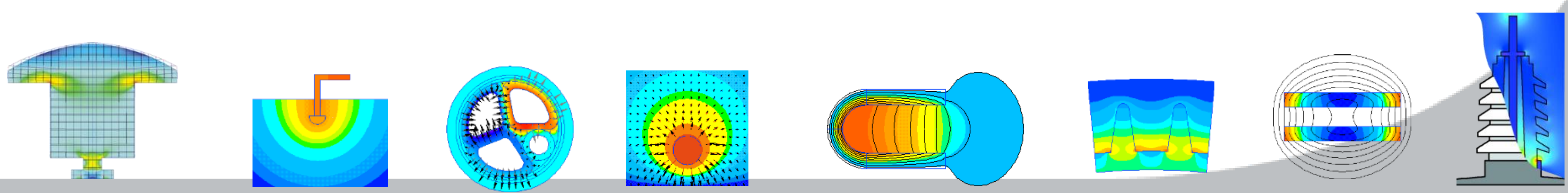

QuickField Analysis Options

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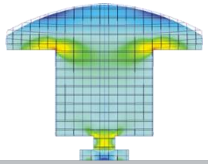
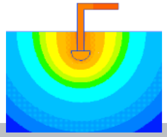
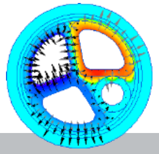
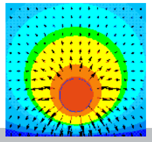
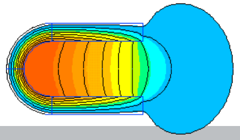
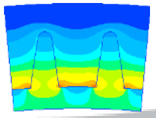
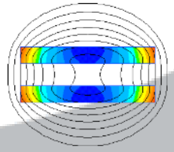
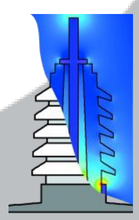









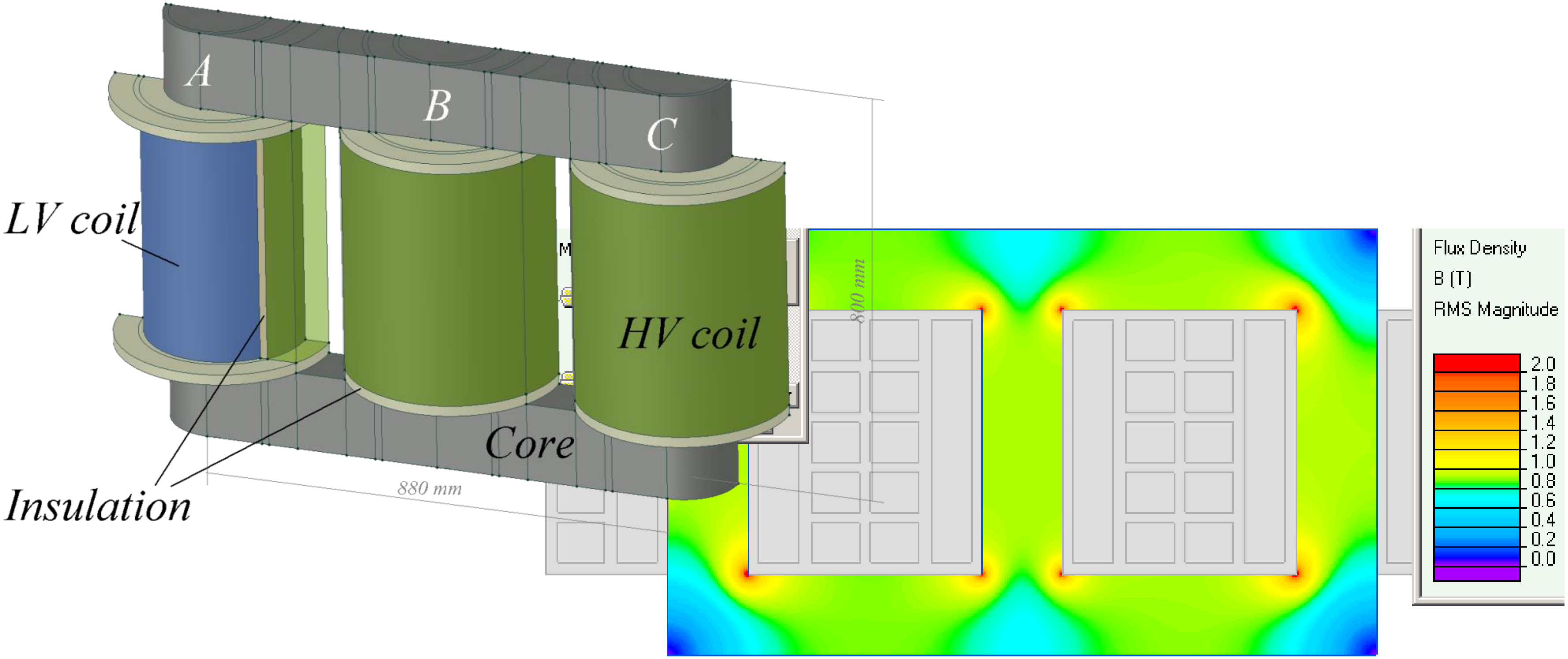
Magnetic analysis applications

Transformers

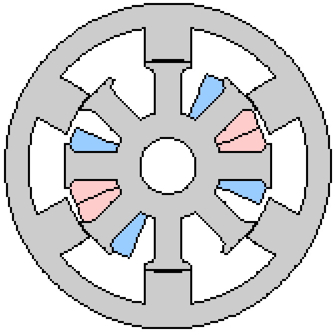
Motors and generators

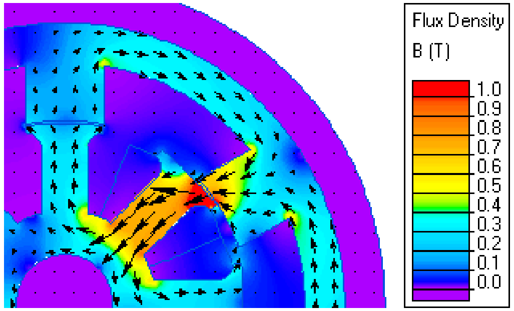
Induction heating

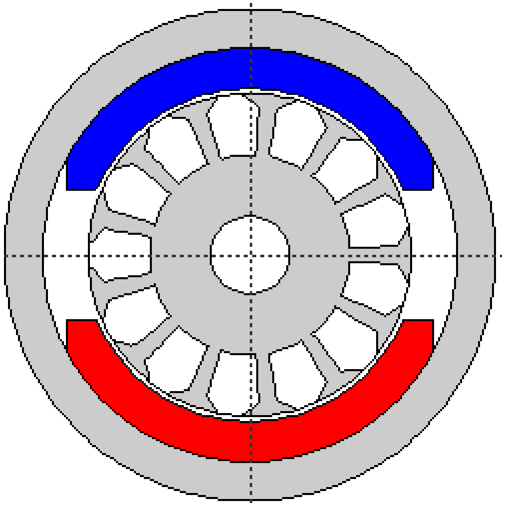
Iron cores in transformers

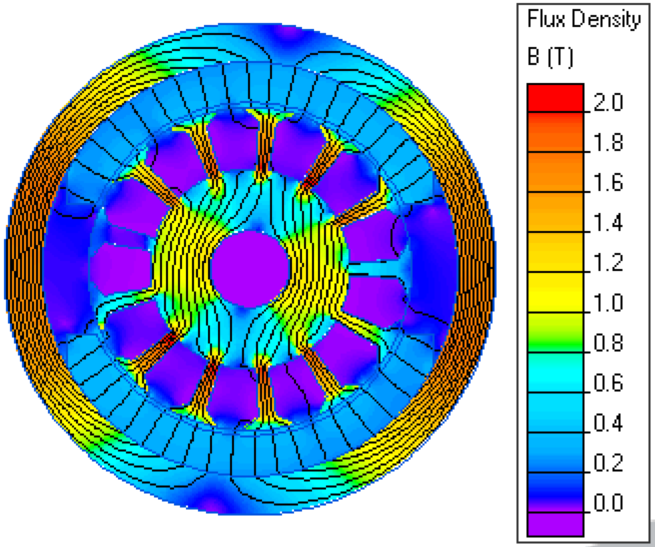


Iron cores in electric motors and generators



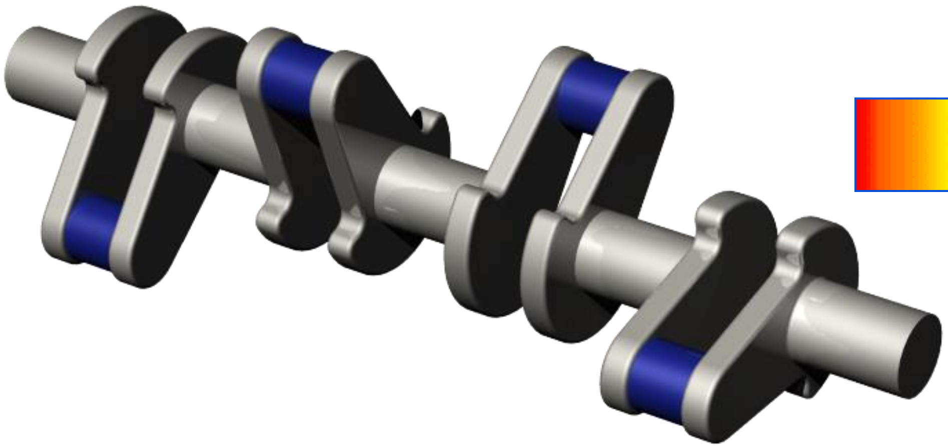


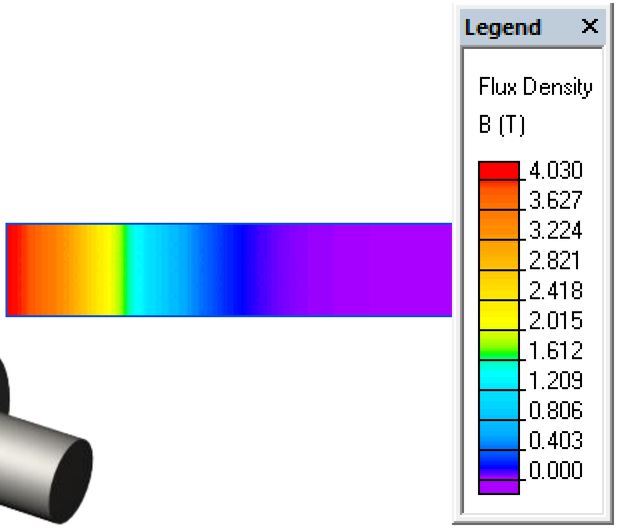


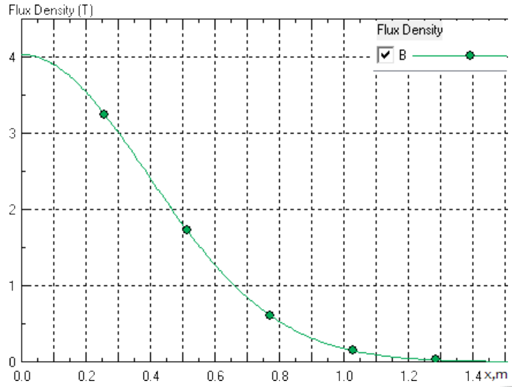


Induction heating of steel parts

Carbon steel alloy crankshaft

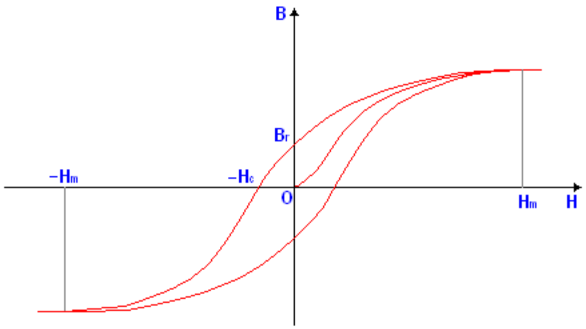






Iron core loss factors

- Hysteresis losses



- Eddy current losses

Iron loss calculation models

Steinmetz's equation
$P = k \cdot f^a \cdot B^c$

Hysteresis models

Bertotti expression:
$P = P_{hyst} + P_{eddy} + P_{excess}$

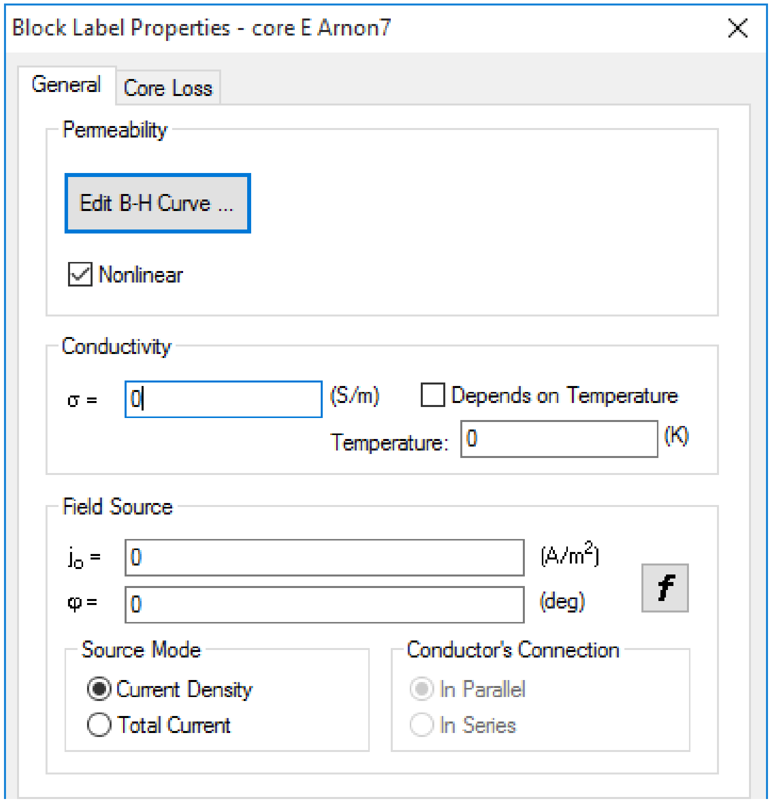
$P_{\mathrm{hyst}} = k_{\mathrm{h}} \cdot f \cdot B_{\mathrm{m}}^2$ – hysteresis
$P_{\mathrm{eddy}} = k_{\mathrm{c}} \cdot f^2 \cdot B_{\mathrm{m}}^2$ – eddy current
$P_{\mathrm{excess}} = k_{\mathrm{e}} \cdot (f \cdot B_{\mathrm{m}})^{3/2}$ – excess

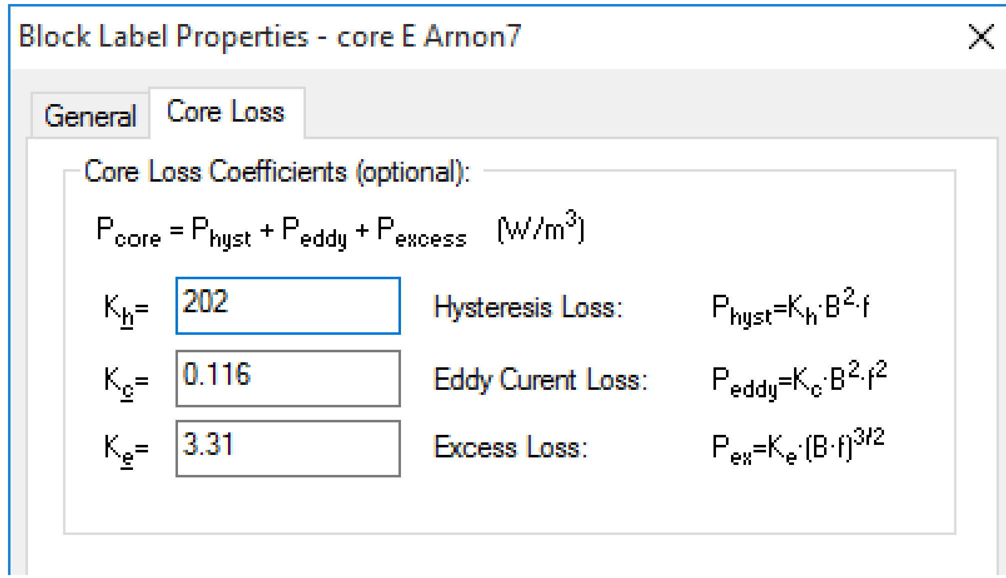
Other models

https://en.wikipedia.org/wiki/Steinmetz's_equation

Iron core losses in AC Magnetics

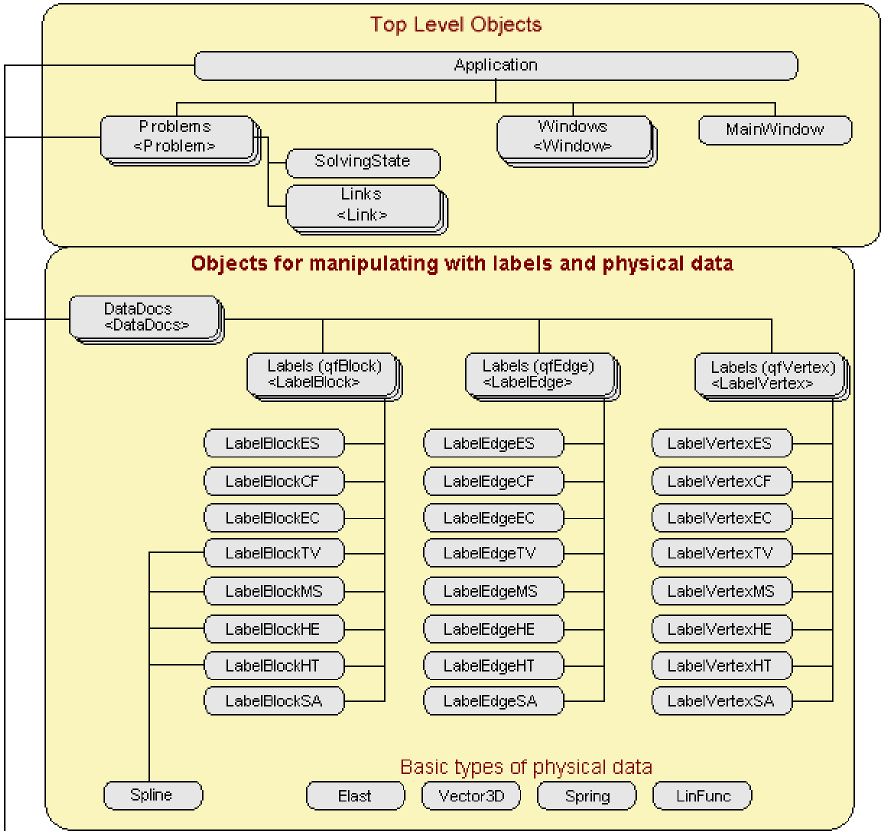
Bertotti expression approach





Alternative approaches in AC Magnetics and Transient Magnetics core losses:

Custom integral calculation using ActiveField Appllication Programming interface



QuickField Difference

Iron core loss calculation with QuickField

Alexander Lyubimtsev
Support Engineer
Tera Analysis Ltd.

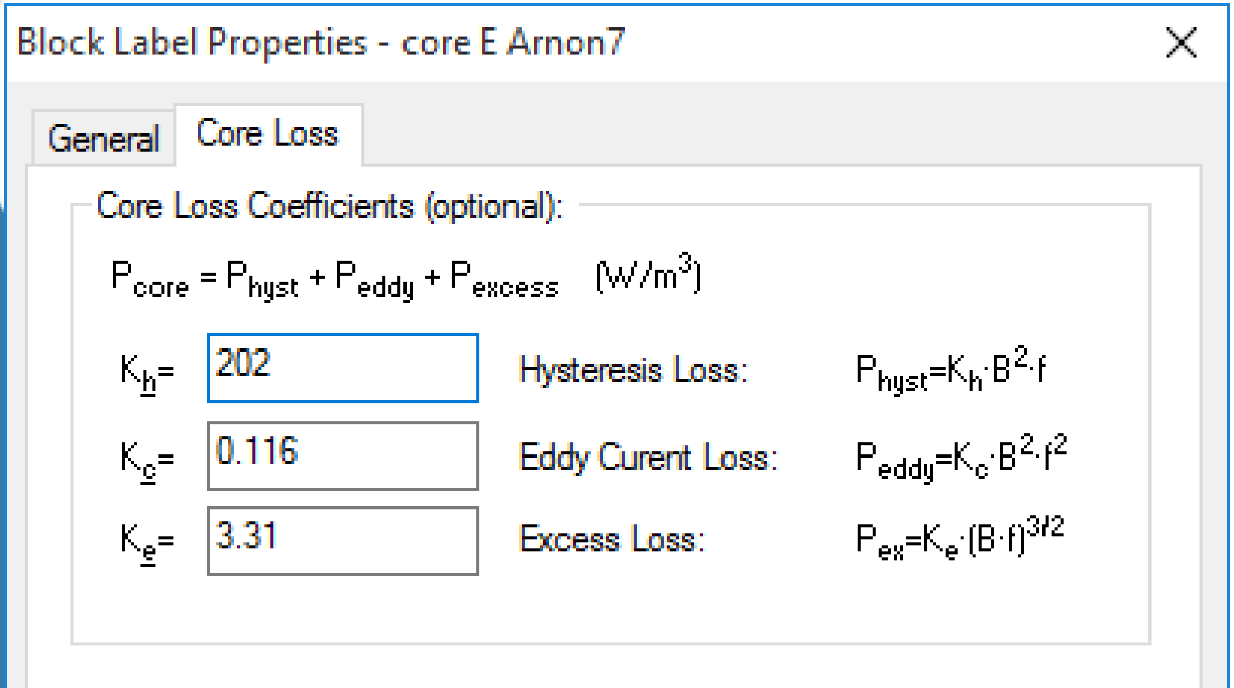
Iron core loss calculation with QuickField

1. Loss coefficient calculation

2. No-load mode of transformer.
   Iron loss calculation.

3. Iron core losses in transient problem

Loss coefficients



Problem specification:

Material density
ρ = 7650 kg/m^3

Task:

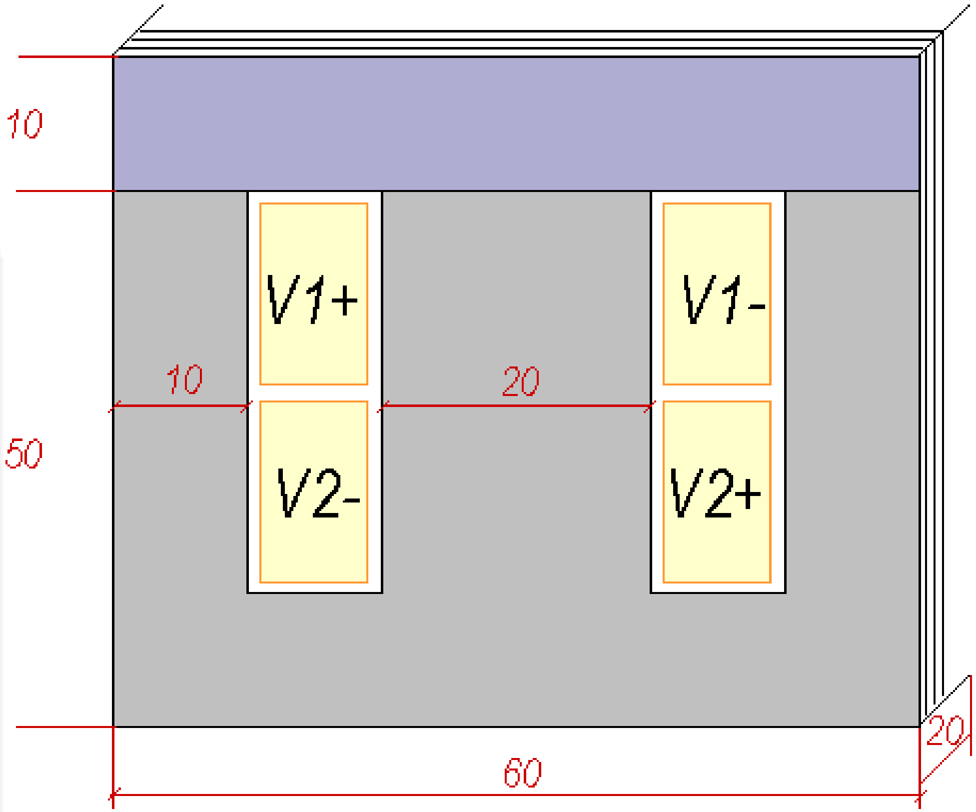
Calculate the iron loss coefficients.

Bertotti expression: $P_{core} = k_h \cdot f \cdot B_m^2 + k_c \cdot f^2 \cdot B_m^2 + k_e \cdot (f \cdot B_m)^{3/2}$

*Core loss data of Arnon™5 non-grain oriented electrical steel are provided by Arnold Magnetics.

https://en.wikipedia.org/wiki/Steinmetz's_equation

No-load mode of transformer



All dimensions are in millimeters

Problem specification:

Core permeability μ =2000
Frequency f = 400 Hz.
Winding 1 (primary):
no-load current 20 mA,
number of turns 400
Core loss coefficients:
$k_h = 124$
$k_c = 0.0621$
$k_e = 1.86$

Bertotti expression $P_{core} =$
$$k_h \cdot f \cdot B_m^2 + k_c \cdot f^2 \cdot B_m^2 + k_e \cdot (f \cdot B_m)^{3/2}$$

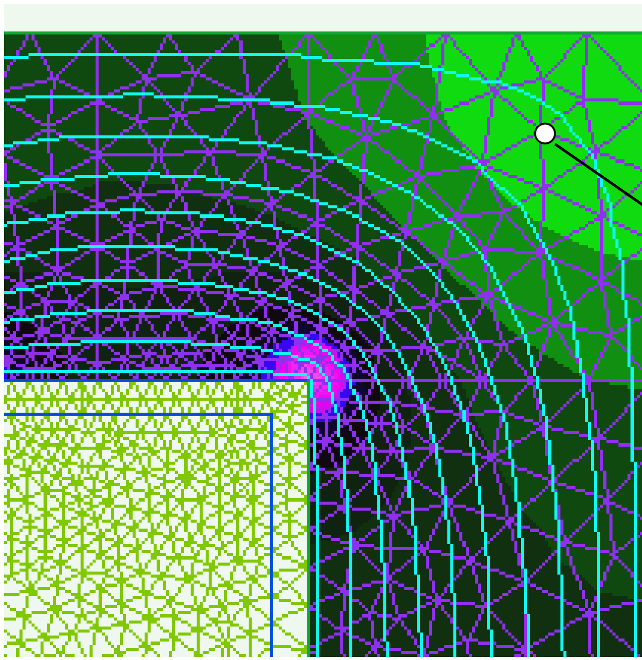
Task:

Calculate the core losses in the no-load mode of transformer.

http://quickfield.com/advanced/laminated_core_iron_loss.htm

Custom integral programming interface

QuickField



Your program

1	**Core Loss Calculation**		
2			
3	1. Open simulation results in QuickField and bu		
4	2. Specify core loss coefficients		
5	$P = (K_h \cdot f + K_c \cdot f^2) \cdot B^2 + K_e \cdot (f \cdot B)^{1.5}$		
6	K_h	124	
7	K_c	0,0621	
8	K_e	1,86	
9			
10	Calculate Core Loss		
11			
12			
13	Frequency	400	Hz
14	Flux density	9,10654E-11	T
15	Loss	1,29315E-11	W
16	Total Loss		W

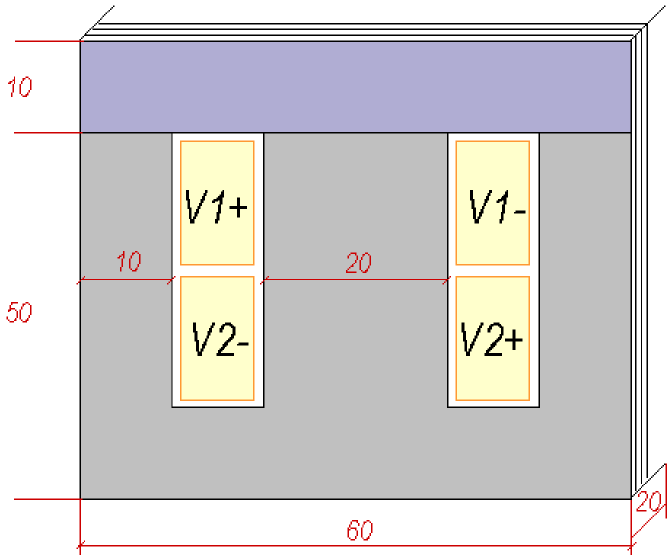
Field data
in the mesh node

Loss data

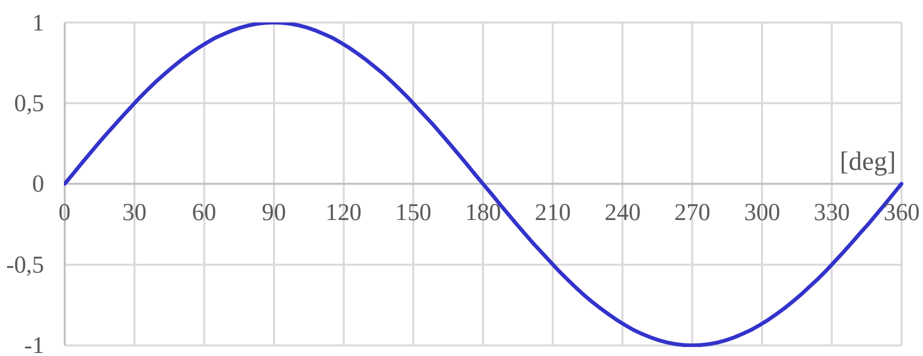
Custom function: $k_h \cdot f \cdot B_m^2 + k_c \cdot f^2 \cdot B_m^2 + k_e \cdot (f \cdot B_m)^{3/2}$

http://quickfield.com/advanced/laminated_core_iron_loss.htm

Transient excitation mode (sin)



All dimensions are in millimeters



Problem specification:

Core permeability μ =2000

Loss coefficients:

k_h = 124

k_c = 0.0621

k_e =1.86

Frequency f = 400 Hz.

Winding 1 (primary):

no-load current 20 mA,

number of turns 400,

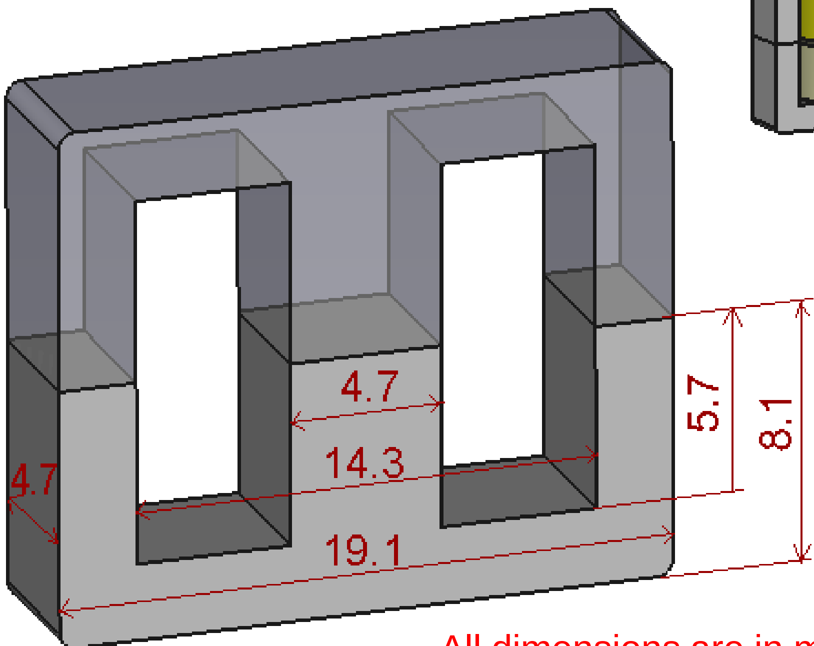
Bertotti expression P_{core} =

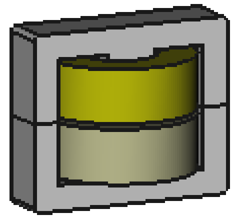
$$k_h \cdot f \cdot B_m^2 + k_c \cdot f^2 \cdot B_m^2 + k_e \cdot (f \cdot B_m)^{3/2}$$

Task:

Calculate the core losses in the transient excitation mode of transformer.

Transient excitation mode

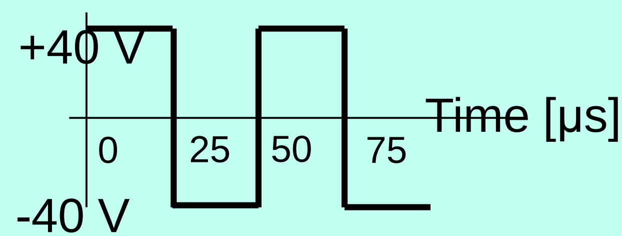




All dimensions are in millimeters

Problem specification:

Core type: 3C81-E
Core permeability μ =2700
Frequency f = 20 kHz.
Winding 1 (primary):
voltage 40 V,
number of turns 80,



Core loss [W/m^3]

$$P_{core} = \max(k_1 f^{\alpha 1} B^{\beta 1};\ k_2 f^{\alpha 2} B^{\beta 2})$$

Task:

Calculate core losses in no-load mode

Testing Core Loss for Rectangular Waveforms, Phase II Final Report,
21 September 2011 by Charles R. Sullivan and John H.Harris; Thayer School of Engineering at Dartmouth.