CORE DESIGN

1. DC Bias Fit Formula
2. Core Loss Fit Formula
3. Core Selection Chart
4. Core Design Tool
5. Core Design Example
6. High Efficiency Core Design

Chang Sung Corporation CSC

1. DC Bias Fit Formula

Powder Core DC Bias Characteristics

• Air Gap

Large Air Gap | Distributed Air Gap

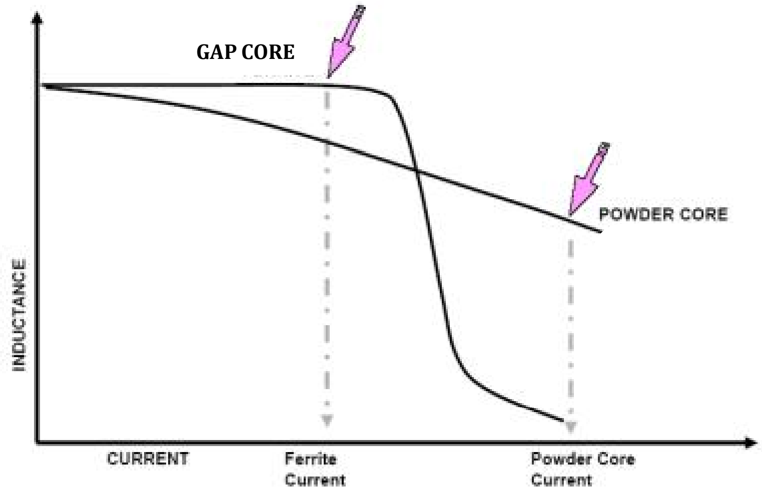
↓

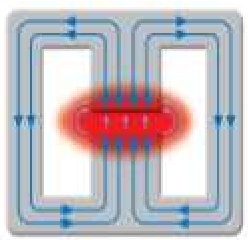
Lower effective perm.(μ_e)

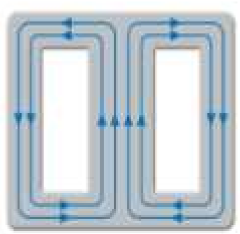
↓

Better DC-Bias

• Soft Saturation







- Higher Inductance at Large Current
- Low Core Loss
- Minimized Audible Noise
- Free from Leakage Flux

  →Less Heat Generation, EMI Noise

1. DC Bias Fit Formula

(1) DC Bias Fit Formula Example1 : Sendust 26μ

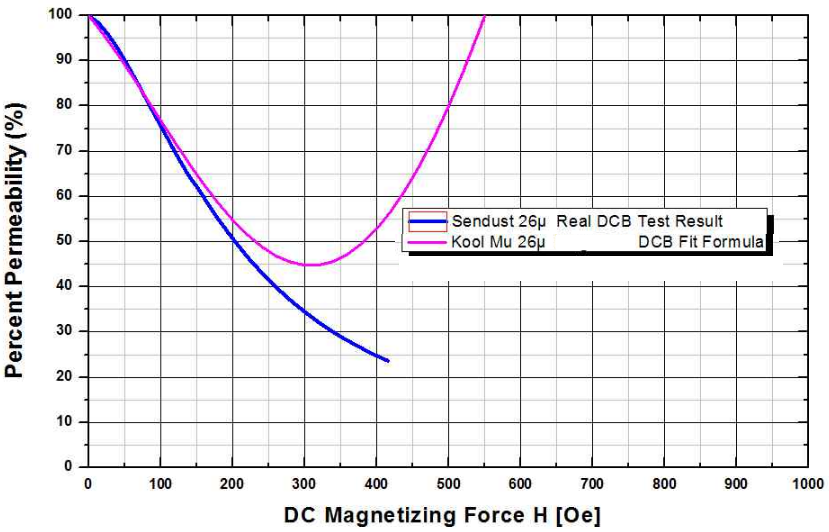
Permeability versus DC Bias Curves

Fit Formula (refer to curves for units)

μ (per unit) $= a + bT + cT^2 + dT^3 + eT^4$

where:

		a	b	c	d	e
MPP	14μ	1	-6.00E-05	-7.00E-06	1.00-E-08	-5.00E-12
	26μ	1	-5.00E-04	-2.00E-05	6.00E-08	-5.00E-11
	60μ	1	-3.00E-04	-2.00E-04	1.00E-06	-3.00E-09
	125μ	1	-1.00E-03	-5.00E-04	8.00E-06	-3.00E-08
	147μ	1	-3.20E-03	-6.00E-04	8.00E-06	-3.00E-08
	160μ	1	-1.90E-03	-8.00E-04	2.00E-05	-8.00E-08
	173μ	1	-7.00E-04	-1.20E-03	3.00E-05	-2.00E-07
	200μ	1	6.70E-03	-2.40E-03	6.00E-05	-5.00E-07
	300μ	1	-3.40E-03	-3.00E-03	1.00E-04	-1.00E-06
	550μ	0.95	-3.77E-02	-3.22E-02	4.40E-03	-2.00E-04
High Flux	14μ	1	6.00E-04	-1.00E-05	4.00E-08	-5.00E-11
	26μ	1	8.00E-04	-3.00E-05	9.00E-08	-1.00E-10
	60μ	1	-5.00E-04	-6.00E-05	4.00E-07	-6.00E-10
	125μ	1	1.10E-03	-3.00E-04	3.00E-06	-9.00E-09
	147μ	1	1.30E-03	-4.00E-04	4.00E-06	-1.00E-08
	160μ	1	1.40E-03	-5.00E-04	6.00E-06	-3.00E-08
Kool Mμ	26μ	1	-1.90E-03	-7.00E-06	3.00E-08	-2.00E-11
	40μ	1	-2.80E-03	-3.00E-05	2.00E-07	-3.00E-10
	60μ	1	-6.80E-03	-1.00E-05	2.00E-07	-5.00-10
	75μ	1	-8.60E-03	-6.00E-05	1.00E-06	-3.00E-09
	90μ	1	-1.26E-02	-3.00E-06	8.00E-07	-3.00E-09
	125μ	1	-1.60E-02	-7.00E-05	3.00E-06	-2.00E-08
XFLUX	60μ	1	-1.20E-03	-3.00E-05	1.00E-07	-1.00E-10



- 0~200 Oe : DCB Fit Formula Graph is similar to Real test result.
- 200 Oe ~ : There are big difference between Real and Fit Formula Graph.

1. DC Bias Fit Formula

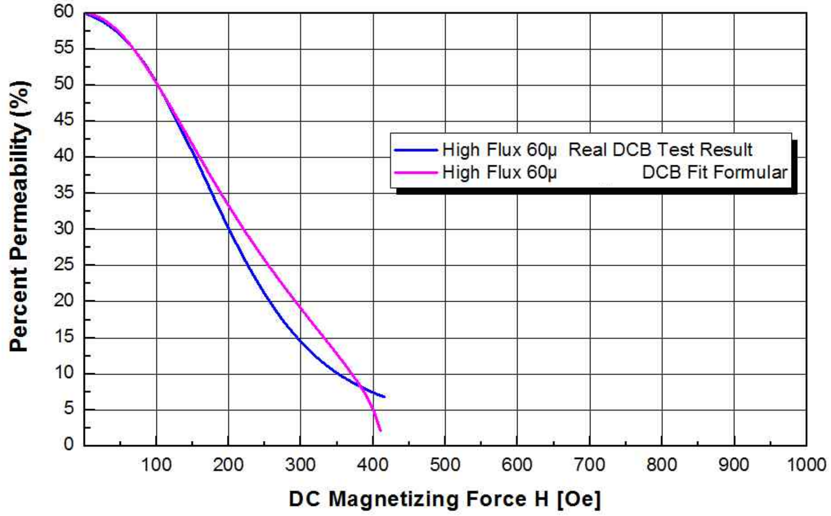
(2) DC Bias Fit Formula Example2 : High Flux 60μ

Factors of Permeability vs. DC bias Fit Formula

$$\mu_{eff} = \sqrt{\frac{\mu_0^2 + a\mu_0^3 H + b\mu_0^4 H^2}{1 + c\mu_0 H + d\mu_0^2 H^2}}$$

▶ High Flux

μ_0	a	b	c	d
14	-7.6531E-06	-3.2799E-09	1.4286E-06	5.1020E-09
26	-2.4556E-05	-1.7069E-09	1.1538E-05	5.9172E-09
60	-2.8972E-05	-4.6296E-10	-2.5000E-05	8.3333E-09
125	-3.4861E-05	3.0720E-10	-3.5200E-05	6.4000E-09
147	-4.5981E-05	5.6666E-10	-4.5578E-05	9.2554E-09
160	-4.9000E-05	6.1035E-10	-4.1250E-05	1.1719E-08



- 0~150 Oe : DCB Fit Formula Graph is similar to Real test result.
- 150 ~410 Oe ~ : There are some difference between Real and Fit Formula Graph.
- 410 ~ : With the above Fit formula, it is not possible to predict permeability.

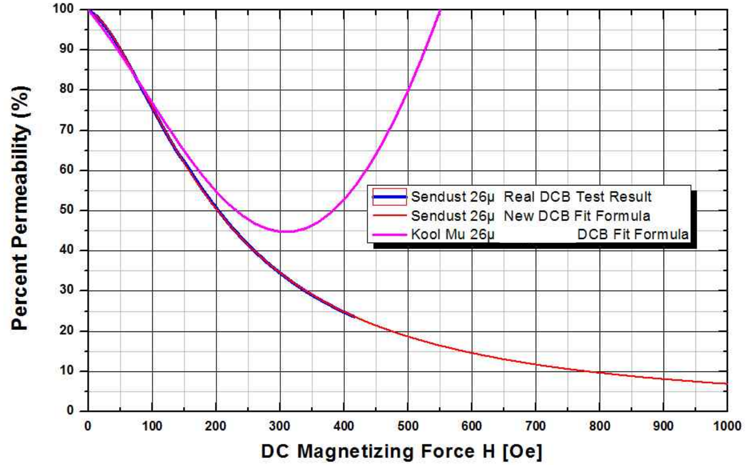
→ For the punctual prediction of permeability at high current , new Fit formula is required.

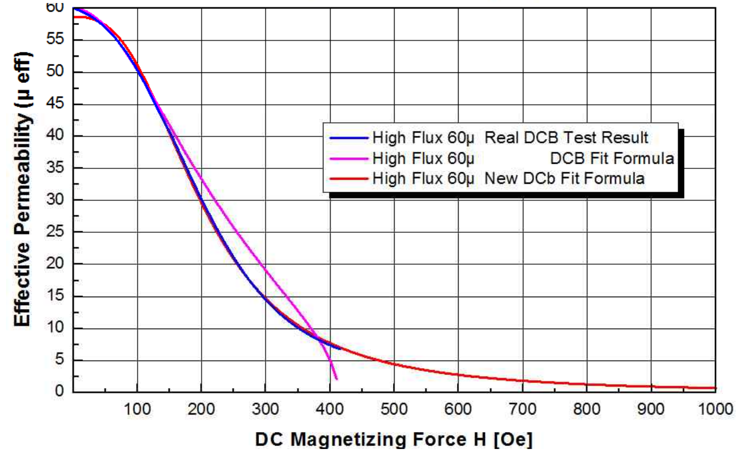
(3)New DC Bias Fit Formula (%Perm.)

$$\% Perm. = \frac{1}{a + bH^c}$$

H : DC Magnetizing Force [Oe]

a, b, c : coefficients





- **0~400 Oe : Real test result and new DC Bias Fit Formula match up very well.**
- **400 Oe ~ : New DC Bias Fit Formula coefficients are determined based on real test result from 0 to 400 Oe, it is possible to predict permeability using that formula.**

→New DC Bias Fit Formula coefficients a, b and c as a function of $\% Perm. = \frac{1}{a + bH^c}$ **are used in CSC catalog 2012 version**

1. DC Bias Fit Formula

(4)New DC Bias Fit Formula Coefficients (Effective Perm.)

$$\mu_{eff} = \frac{1}{a + bH^c}$$

H : DC Magnetizing Force [Oe]

a, b, c : coefficients

Material	ui	a	b	c
MPP	026	0.0385	4.04E-07	2.081
	060	0.0167	1.70E-07	2.454
	125	0.0080	1.71E-07	2.663
	147	0.0068	2.76E-07	2.612
	160	0.0062	2.67E-07	2.645
	173	0.0058	3.09E-07	2.667
	200	0.0050	1.73E-07	2.820
High Flux	026	0.0385	6.84E-08	2.196
	060	0.0167	5.39E-08	2.419
	125	0.0080	8.30E-08	2.523
	147	0.0068	3.12E-08	2.808
	160	0.0062	6.92E-08	2.641
Sendust	026	0.0385	4.16E-06	1.709
	060	0.0167	4.70E-06	1.797
	075	0.0133	6.19E-06	1.758
	090	0.0111	9.07E-06	1.739
	125	0.0080	1.60E-05	1.681
Mega Flux®	019	0.0527	6.37E-09	2.424
	026	0.0385	2.66E-07	1.944
	050	0.0195	1.01E-06	1.859
	060	0.0167	6.43E-07	1.955
	075	0.0133	1.82E-06	1.804
	090	0.0111	2.47E-06	1.809
HS	019	0.0523	2.10E-07	2.090
	026	0.0396	8.91E-09	2.668
	060	0.0170	3.28E-07	2.145
	075	0.0138	5.06E-07	2.083
	090	0.0114	2.05E-06	1.853

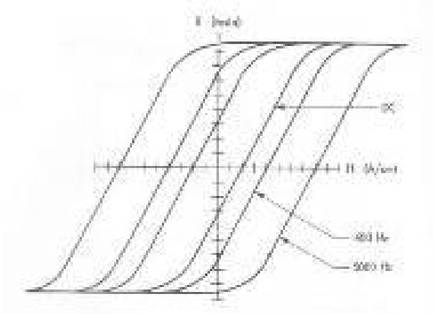
2. Core Loss Fit Formula

Core Loss

•Core loss (or iron loss) is a form of energy loss that occurs in electrical transformers and other inductors. The loss is due to a variety of mechanisms related to the fluctuating magnetic field, such as eddy currents and hysteresis.

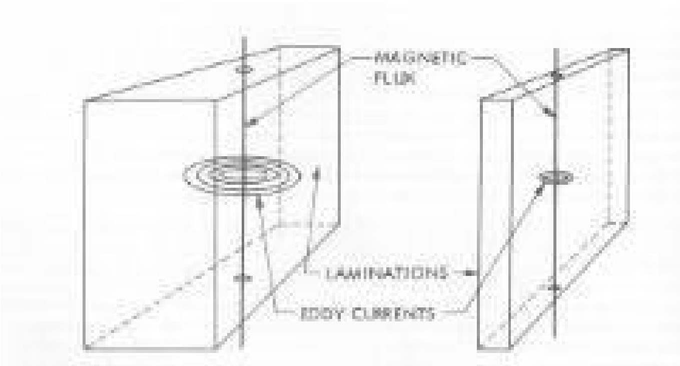
1)Hysteresis loss :
Equal to area of Hysteresis curve

$$P_h = \frac{kH_c B_m}{\pi} \propto f$$



2)Eddy current loss :
Induced eddy current in material (Joule' heat)

$$P_e = W_e f = \frac{\pi^2 d^2 B^2 f^2}{c\rho} \propto \frac{f^2}{\rho}$$



2. Core Loss Fit Formula

(1) Steinmetz Equation

I. INTRODUCTION

THE CALCULATION of core losses in inductive components is difficult and has not yet been entirely solved. Particularly, the influence of a dc bias on the losses is not entirely clarified. The most used equation that characterizes core losses is the power equation [1][1]

$$P_v = k f^\alpha \hat{B}^\beta \quad (1)$$

where $\hat{B}$ is the peak induction of a sinusoidal excitation with frequency f, P_v is the time-average power loss per unit volume, and k, α, β are material parameters. The equation is often referred to as the Steinmetz equation, named after Charles P. Steinmetz, who proposed a similar equation, without the frequency dependence, in 1892 [2]. The material parameters k, α, and β are accordingly referred to as the Steinmetz parameters. They are valid for a limited frequency and the flux density range. Unfortunately, the Steinmetz equation is only valid for sinusoidal excitation. This is a huge drawback, because in power electronics applications, the material is mostly exposed to nonsinusoidal flux waveforms.

Different approaches have been developed to overcome this limitation and determine losses for a wider variety of waveforms.

Core Losses Under the DC Bias Condition Based on Steinmetz Parameters

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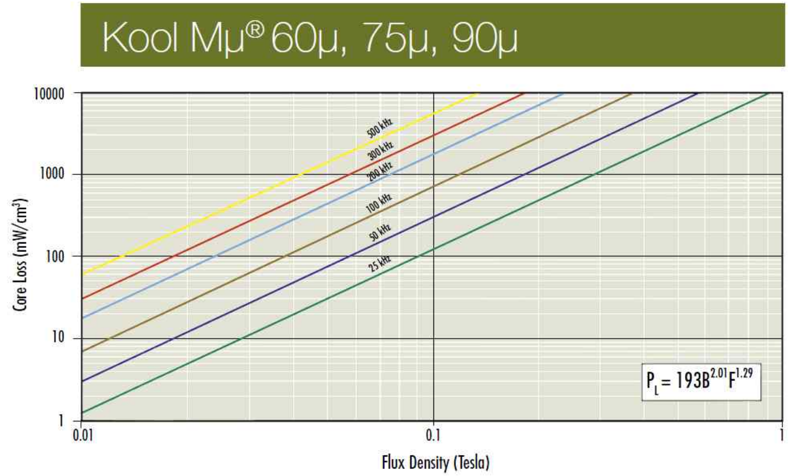
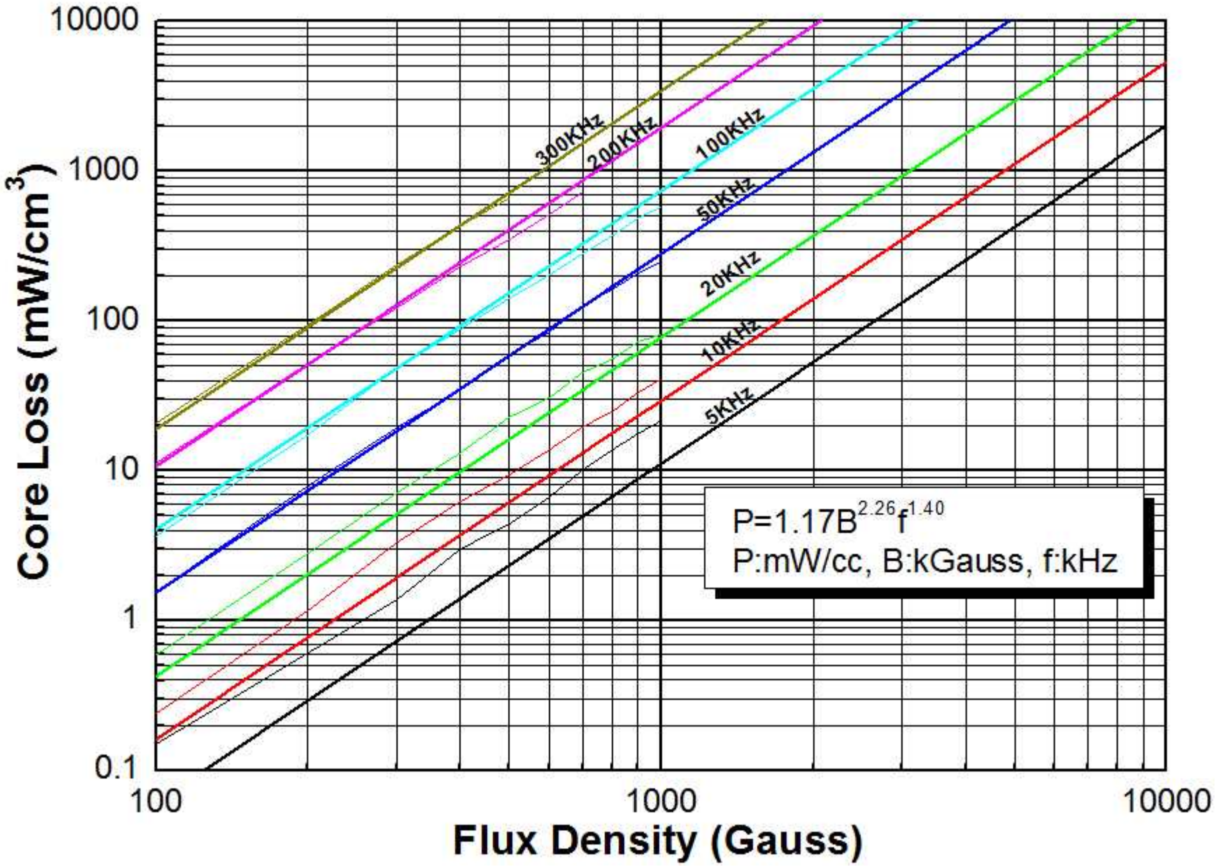


$$CL(mW/cm^3) = \frac{f}{\frac{a}{B^3} + \frac{b}{B^{2.3}} + \frac{c}{B^{1.65}}} + d \cdot B^2 \cdot f^2$$

(2) Steinmetz Equation vs Real Core Loss Test Result (Sendust 60μ)



- f = 50kHz ~ 300kHz

  : Real test results are similar to Core Loss Fit Formula lines.

- f = 5 ~ 20kHz

  : Core Loss Fit Formula lines are much lower than Real test results lines.

→For calculating Core Losses at lower Frequency, new Fit formula is required.

※Core Loss Test Equipment : SY-8217 B-H Analyzer
Steinmetz Equation is based on real test result.

(3) New Core Loss Fit Formula

(Sendust 60μ)

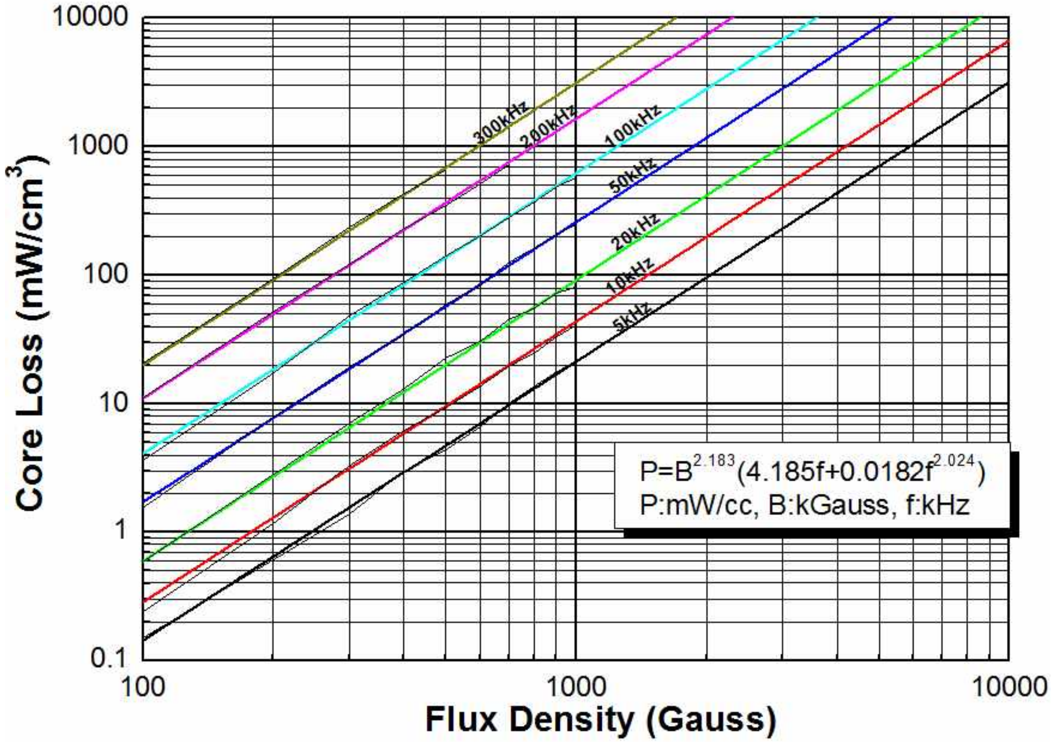
$$P = B^a(bf + cf^d)$$

P : Core Loss [mW/cc]

B : Flux Density [kGauss]

f : Frequency [kHz]

a, b, c, d : coefficients



- **f = 5~300 kHz**

  : Real Core Loss test results at all frequencys and new Core Loss Fit Formula prediction match up very well.

※Core Loss Test Equipment : SY-8217 B-H Analyzer

2. Core Loss Fit Formula

(4) New Core Loss Fit Formula coefficients

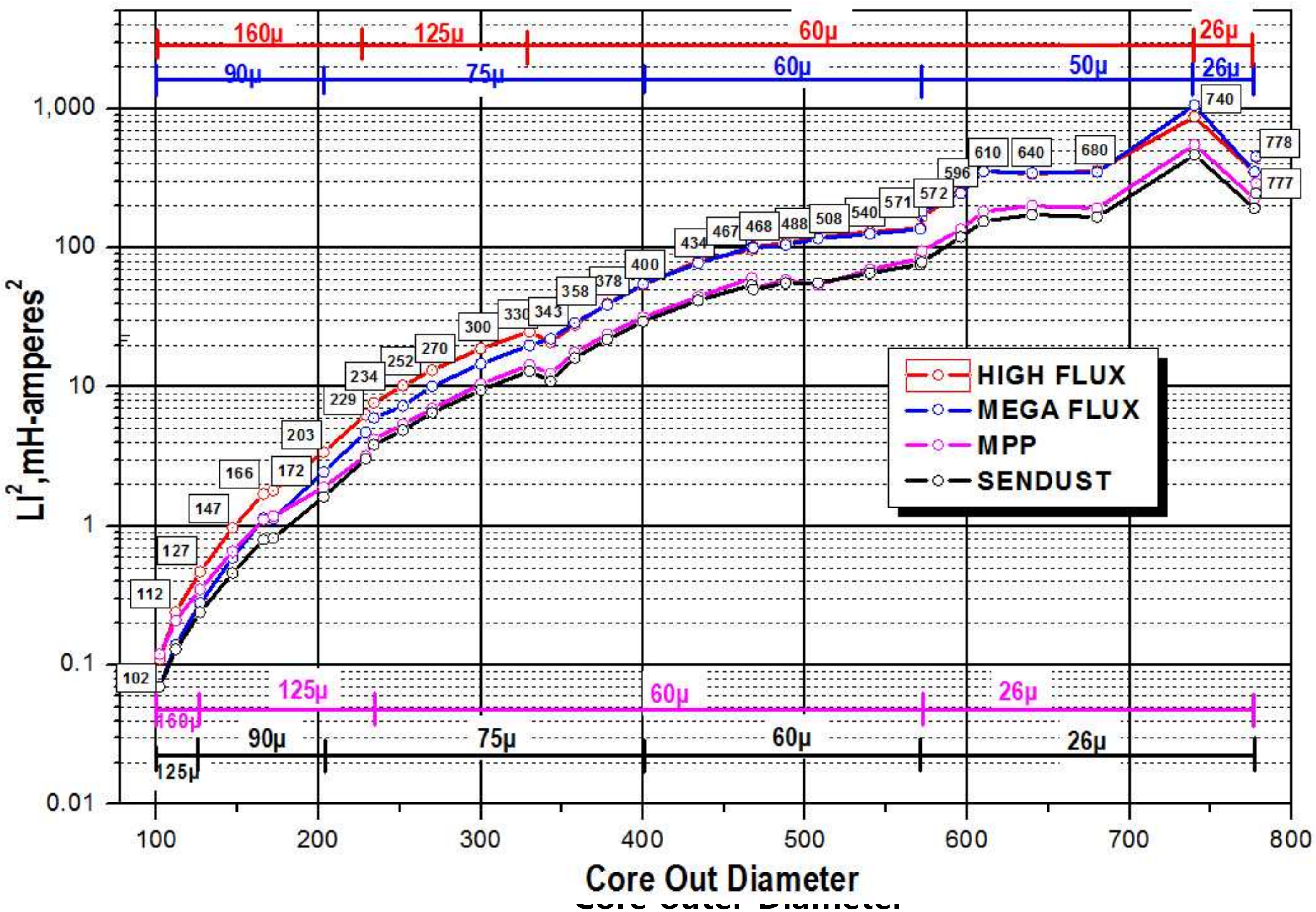
$$P = B^a(bf + cf^d)$$

Material	ui	a	b	c	d
MPP	026	2.285	3.379	0.0032	2.390
	060	2.183	2.485	0.0125	2.099
	125	2.028	1.197	0.1865	1.750
	147	2.026	0.865	0.2634	1.712
	160	2.026	0.865	0.2634	1.712
	173	2.026	0.865	0.2634	1.712
	200	2.045	0.848	0.3513	1.716
High Flux	026	2.252	4.081	0.0006	2.736
	060	2.284	3.050	0.0023	2.397
	125	2.165	1.736	0.1793	1.780
	147	2.104	2.117	0.1131	1.899
	160	2.104	2.117	0.1131	1.899
Sendust	026	2.048	4.245	0.0215	1.990
	060	2.183	4.185	0.0182	2.024
	075	2.207	4.518	0.0244	1.967
	090	2.207	4.518	0.0244	1.967
	125	2.207	4.518	0.0244	1.967
Mega Flux®	019	2.166	9.918	0.0519	2.061
	026	2.166	9.918	0.0519	2.061
	050	2.145	8.874	0.0632	1.980
	060	2.145	8.874	0.0632	1.980
	075	2.145	8.874	0.0632	1.980
	090	2.145	8.874	0.0632	1.980
HS	019	1.878	2.277	0.0053	2.135
	026	1.878	2.277	0.0053	2.135
	060	2.275	2.830	0.0312	1.953
	075	2.269	3.677	0.0411	1.930
	090	2.269	3.677	0.0411	1.930

3. Core Selection Chart

(1) Core Selection Chart(Toroidal)

• Energy Storage Capacity : LI^2 [L=Inductance(mH), I=Current(A)]



4. Core Design Tool

(1) Core Design Tool(Toroidal)

Inductor Design

Material	OD
HS(HS)	610E20
STACKING	2

Core Dimension

	OD(max)	ID(min)	HT(max)	Stack HT
Before coating(mm)	62	32.6	20	40
After coating(mm)	63.1	31.37	21.27	42.54

Path length(㎝)	14.37
Cross Section Area(㎠)	5.88
Window Area(㎠)	7.73
Volume(cc)	84.496
Surface Area(㎠)	173.3

Total Loss & Delta T

Perm.	Total Loss(W)		Delta T	
	DC	AC	DC	AC
019	21.8	31.9	56	77
026	21.8	31.9	56	77
060	22.1	37.6	57	88
075	23.1	42.5	59	98
090	23.1	42.5	59	98
	#N/A	#N/A	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A

Design Parameter

Turns	27	Winding Factor(%)	44	DCR(mΩ) @ 20℃	4.7
Wire Eff. Area(㎟)	12.56	RMS Current (A)	55.0	Temp of Wire(℃)	88
Wire length/T(㎝)	12.85	Peak Current (A)	65.0	DCR(mΩ) @ T(℃)	6.0
Wire Material	Copper	Frequency (kHz)	100.00	Wire loss @Irms(W)	18.0
Current Density	4.38 A/㎟	Ripple Current (ΔI)	10.0 A	Wire loss @Ipeak(W)	25.1
Wire Dia(mm)	Φ 4.00	Required L (μH) @ Ipeak	110.0	Wire Weight(g)	390
Multi Ply Wire Dia(mm)	Φ 2.00	Ply 4 P	1Layer= 21 turns	2Layer= 16 turns	3Layer= 10 turns
		12.57	Graph range	0A ~	78.0 A

DC Bias Characteristics

Curr.	Perm.	019	026	060	075	090		
	H(Oe)\AL		132 mH	306 mH				
0.0 A	-	#N/A	96.2 μH	223.1 μH	#N/A	#N/A	#N/A	#N/A
18.3 A	43	70.9	94.1	206.5	247.2	275.3	#N/A	#N/A
36.7 A	87	68.6	91.5	172.1	193.6	193.1	#N/A	#N/A
55.0 A	130	65.0	86.1	132.5	140.6	132.1	#N/A	#N/A
65.0 A	153	62.5 μH	82.0 μH	113.2 μH	117.2 μH	108.5 μH	#N/A	#N/A
78.0 A	184	59.0	75.7	91.9	92.9	85.5	#N/A	#N/A
Lrated / Linitial			85.2%	50.7%				

Core Loss

Perm.	ΔI	L@ Ipeak	Flux Density(G)		Core Loss(mW/cc)		Core Loss(W)	
			DC(ΔB/2)	AC(ΔB)	DC	AC	DC	AC
019	17.6	63	346	693	45	164	3.8	13.8
026	13.4	82	346	693	45	164	3.8	13.8
060	9.7	113	346	693	48	232	4.0	19.6
075	9.4	117	346	693	60	289	5.1	24.5
090	10.1	109	346	693	60	289	5.1	24.5
					#N/A	#N/A	#N/A	#N/A
					#N/A	#N/A	#N/A	#N/A

5. Core Design Example

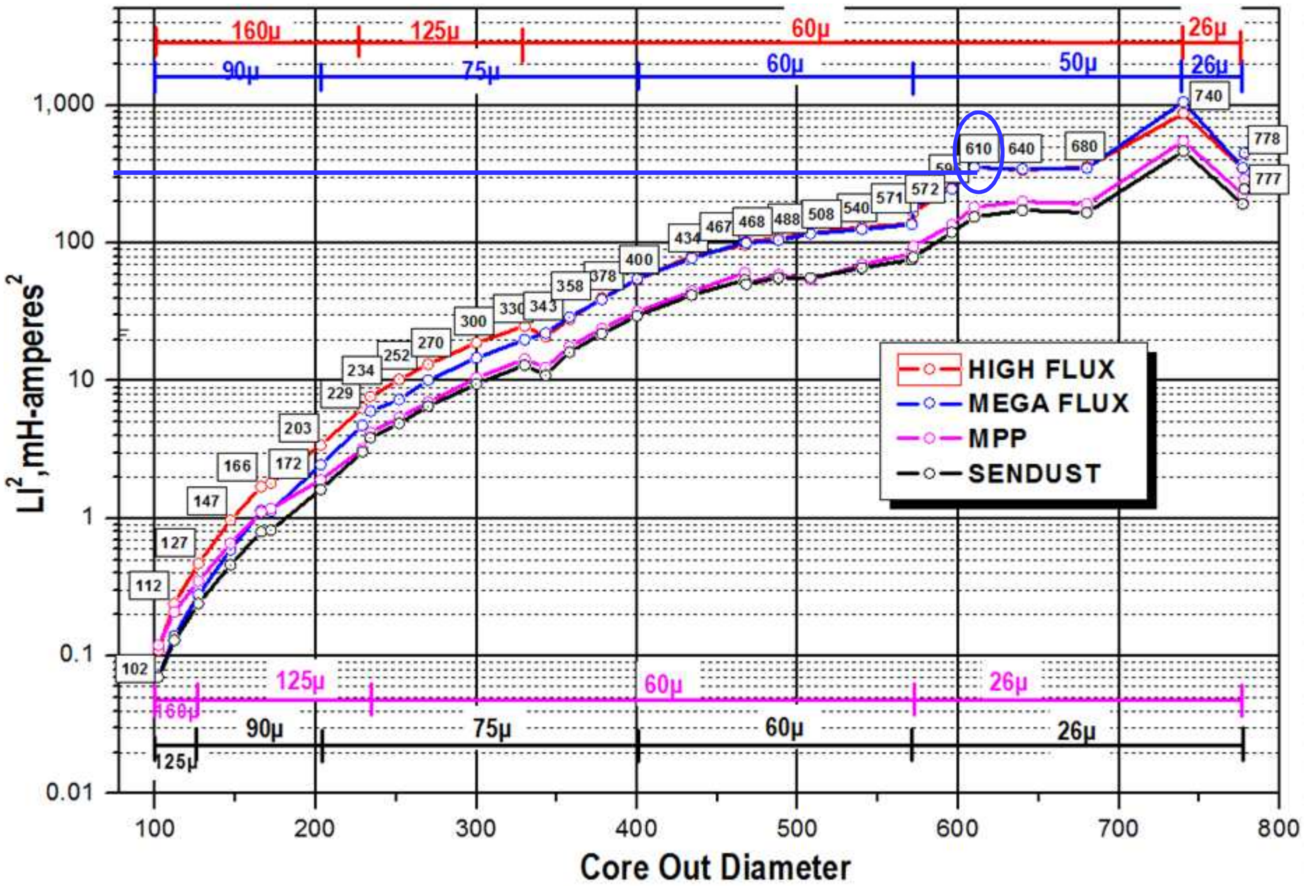
Toroidal Core Design

* Information

- Application : 9kW Solar Inverter AC Filter Inductor
- Switching Frequency : 17kHz
- I rms : 13A
- I peak : 21A
- ⊿I : 6.3A
- Inductance : 700㎌H @21A

L(21A)=700μH

• **Energy Storage Capacity : LI² [L=Inductance(mH), I=Current(A)]=0.7 x 21²=308**



Inductance	700.0 μH
Current	21.0 A
LI²	308.7

→ **Material = Mega Flux, Size = OD61.0mm Size**

5. Core Design Example

1. **Material & Size Input : Material = Mega Flux, OD = 610**
2. **Design Data Input : RMS Current=13A, Peak Current=21A, Frequency=17kHz**
   Ripple Current=6.3A, Required L=700μH
3. **Wire : Wire Material → Current Density → Turns changing to meet the target L**
   (Winding Factor should be lower than 45%)

Inductor Design

Material	OD
CK(MegaFlux)	610
STACKING	1

Core Dimension

	OD(max)	ID(min)	HT(max)	Stack HT
Before coating(mm)	62	32.6	25	25
After coating(mm)	63.1	31.37	26.27	26.27

Path length(㎝)	14.37
Cross Section Area(㎠)	3.675
Window Area(㎠)	7.73
Volume(cc)	52.810
Surface Area(㎠)	125.1

Total Loss & Delta T

Perm.	Total Loss(W)		Delta T	
	DC	AC	DC	AC
026	11.1	31.1	42	99
050	10.6	28.4	40	92
060	10.6	28.4	40	92
075	10.6	28.4	40	92
090	10.6	28.4	40	92
	#N/A	#N/A	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A

Design Parameter

Turns	77	Winding Factor(%)	38	DCR(mΩ) @ 20℃	31.9
Wire Eff. Area(㎟)	3.80	RMS Current (A)	13.0	Temp of Wire(℃)	20
Wire length/T(㎝)	9.27	Peak Current (A)	21.0	DCR(mΩ) @ T(℃)	31.9
Wire Material	Copper	Frequency (kHz)	17.00	Wire loss @Irms(W)	5.4
Current Density	3.42 A/㎟	Ripple Current (ΔI)	6.3 A	Wire loss @Ipeak(W)	14.1
Wire Dia(mm)	Φ 2.20	Required L (μH) @ Ipeak	700.0	Wire Weight(g)	243
Multi Ply Wire Dia(mm)	Φ 1.00	Ply 5 P	1Layer= 41 turns	2Layer= 36 turns	3Layer= 30 turns
		3.93	Graph range	0A ~	25.2 A

DC Bias Characteristics

Curr.	Perm.	026	050	060	075	090		
	H(Oe)\AL	83 mH	160 mH	192 mH	240 mH	288 mH		
0.0 A	-	492.1 μH	948.6 μH	1,138.4 μH	1,423.0 μH	1,707.6 μH	#N/A	#N/A
4.3 A	29	489.5	950.6	1,121.5	1,368.9	1,572.8	#N/A	#N/A
8.7 A	58	482.9	888.2	1,038.9	1,197.6	1,280.3	#N/A	#N/A
13.0 A	88	472.5	806.2	927.5	1,007.2	999.0	#N/A	#N/A
21.0 A	141	445.5 μH	644.3 μH	711.1 μH	708.5 μH	630.7 μH	#N/A	#N/A
25.2 A	170	428.4	566.5	610.8	590.7	505.2	#N/A	#N/A
Lrated / Linitial		90.5%	67.9%	62.5%	49.8%	36.9%		

Core Loss

Perm.	ΔI	L@ Ipeak	Flux Density(G)		Core Loss(mW/cc)		Core Loss(W)	
			DC(ΔB/2)	AC(ΔB)	DC	AC	DC	AC
026	9.9	446	779	1,558	109	487	5.7	25.7
050	6.8	644	779	1,558	98	435	5.2	23.0
060	6.2	711	779	1,558	98	435	5.2	23.0
075	6.2	708	779	1,558	98	435	5.2	23.0
090	7.0	631	779	1,558	98	435	5.2	23.0
					#N/A	#N/A	#N/A	#N/A
					#N/A	#N/A	#N/A	#N/A

5. Core Design Example

Data Read

1. Select Perm. & Read L– Red color means that perm. meet the target L

2. Read Core Loss: Wave shape is DC → Read DC Loss, AC→ Read AC Loss

3. Read Total Loss & Delta T : Total Loss=Core Loss + Wire Loss

Inductor Design

Material	OD
CK(MegaFlux)	610
STACKING	1

Core Dimension

	OD(max)	ID(min)	HT(max)	Stack HT
Before coating(mm)	62	32.6	25	25
After coating(mm)	63.1	31.37	26.27	26.27

Path length(㎝)	14.37
Cross Section Area(㎠)	3.675
Window Area(㎠)	7.73
Volume(cc)	52.810
Surface Area(㎠)	125.1

Total Loss & Delta T

Perm.	Total Loss(W)		Delta T	
	DC	AC	DC	AC
026	11.1	31.1	42	99
050	10.6	28.4	40	92
060	10.6	28.4	40	92
075	10.6	28.4	40	92
090	10.6	28.4	40	92
	#N/A	#N/A	#N/A	#N/A
	#N/A	#N/A	#N/A	#N/A

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Design Parameter

Turns	77	Winding Factor(%)	38	DCR(mΩ) @ 20℃	31.9
Wire Eff. Area(㎟)	3.80	RMS Current (A)	13.0	Temp of Wire(℃)	20
Wire length/T(㎝)	9.27	Peak Current (A)	21.0	DCR(mΩ) @ T(℃)	31.9
Wire Material	Copper	Frequency (kHz)	17.00	Wire loss @Irms(W)	5.4
Current Density	3.42 A/㎟	Ripple Current (ΔI)	6.3 A	Wire loss @Ipeak(W)	14.1
Wire Dia(mm)	Φ 2.20	Required L (μH) @ Ipeak	700.0	Wire Weight(g)	243
Multi Ply Wire Dia(mm)	Φ 1.00	Ply 5 P	1Layer= 41 turns	2Layer= 36 turns	3Layer= 30 turns
		3.93	Graph range	0A ~	25.2 A

DC Bias Characteristics

Curr.	Perm.	026	050	060	075	090		
	H(Oe)\AL	83 mH	160 mH	192 mH	240 mH	288 mH		
0.0 A	-	492.1 μH	948.6 μH	1,138.4 μH	1,423.0 μH	1,707.6 μH	#N/A	#N/A
4.3 A	29	489.5	950.6	1,121.5	1,368.9	1,572.8	#N/A	#N/A
8.7 A	58	482.9	888.2	1,038	1,197.6	1,280.3	#N/A	#N/A
13.0 A	88	472.5	806.2	927	1,007.2	999.0	#N/A	#N/A
21.0 A	141	445.5 μH	644.3 μH	711.1 μH	708.5 μH	630.7 μH	#N/A	#N/A
25.2 A	170	428.4	566.5	610.8	590.7	505.2	#N/A	#N/A
Lrated / Linitial		90.5%	67.9%	62.5%	49.8%	36.9%		

1

Core Loss

Perm.	ΔI	L@ Ipeak	Flux Density(G)		Core Loss(mW/cc)		Core Loss(W)	
			DC(ΔB/2)	AC(ΔB)	DC	AC	DC	AC
026	9.9	446	779	1,558	109	487	5.7	25.7
050	6.8	644	779	1,558	98	435	5.2	23.0
060	6.2	711	779	1,558	98	435	5.2	23.0
075	6.2	708	779	1,558	98	435	5.2	23.0
090	7.0	631	779	1,558	98	435	5.2	23.0
					#N/A	#N/A	#N/A	#N/A
					#N/A	#N/A	#N/A	#N/A

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6. High Efficiency Core Design

(1) Core Loss

1) P=f(B, f)

: P=Core Loss[mW/cc], B=Flux Density[kGauss], f=Switching Frequency[kHz]

2) Core Loss Curve fit Equation $P = B^a(bf + cf^d)$ (a, b, c, d = constants)

(2) Flux Density

1)B=f(L, I, N, Ae)

→ $B=(L_{DC} \times \Delta I \times 100) / (2 \times N \times Ae)$

: B=Flux Density[kGauss], L_{DC}=Biased Inductance [μH],

ΔI=Ripple Current [A], N=No. of Turns, Ae=Core Cross Section Area [cm^2]

(3) Low Core Loss Design with same Material : Fixed Frequency, Inductance

Categories	Method	Remarks	Disadvantage
Ripple Current	↓	Control Program	
No. of Turns	↑	Low Perm. Core	Wire Loss ↑ Wire Cost ↑
Cross Section Area	↑	Taller Height	Core Cost ↑

(4) Design Example

1) RMS Current = 8A

Peak Current = 12A

Frequency = 100kHz

Ripple Current = 5A

L(12A)=160μH

※ Core Loss Comparison (@50kHz, 1,000G)

Materials	Core Loss
MPP 60μ	170mW/cc
High Flux 60μ	180mW/cc
Sendust 60μ	260mW/c
Mega Flux 60μ	590mW/cc

2) High Flux OD 33mm Design Result (Original Design=CH330125)

Core	Wire			Inductance [μH]		B [Gauss]	Loss [W]		
	Size	Turns	Weight	L(0A)	L(12A)		Core Loss	Copper Loss	Total Loss
CH330125	Φ1.5	50	33g	317	162	1,190	6.6	1.3	7.9
CH330060		58	38g	205	161	1,026	2.6	1.5	4.1
CH330026		82	54g	188	161	726	1.6	2.1	3.7
CH330026E14		71	55g	181	163	639	1.6	2.2	3.7

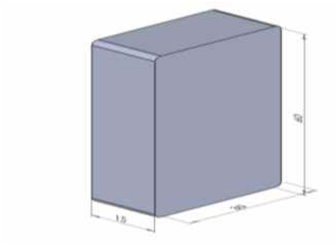
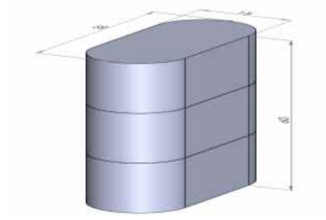
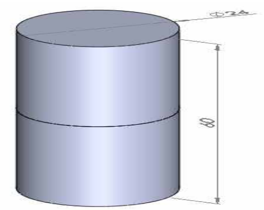
6. High Efficiency Core Design

(1) Wire Loss

Wire Loss = $I^2 \cdot R$ (I : Rated Current [A], R : Resistance of Wire[Ω])

(2) Low Wire Loss Core Design

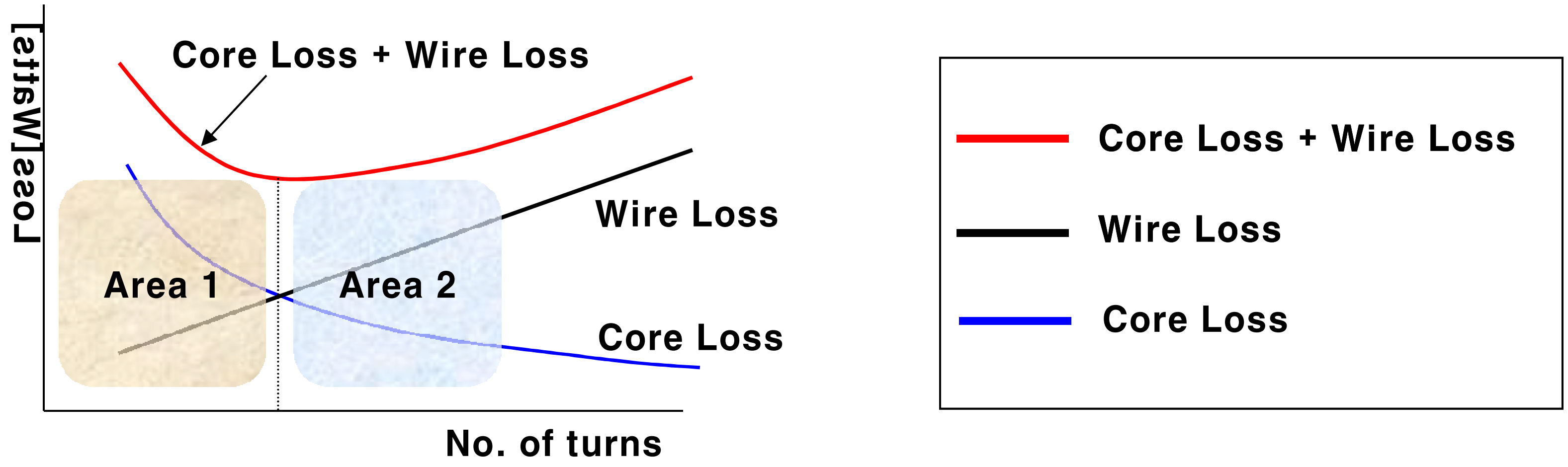
1) Wire Length / Turn should be Smaller

Core Shape	 Block Cores	 Ellipse Cores	 Cylinder Cores
Cross sectional Area(cm^2)	4.5	4.5	4.5
Size	30mm x 15mm	33mm x 15mm (Corner 7.5R)	φ24mm
Wire length / turn(cm)	9	8.31	7.53

2) No. of Turns should be Smaller

→ High Perm. Core

(1) Total Loss vs Turns



❖Total Loss = Core Loss + Wire Loss

❖No. of Turns ↑ → Wire Loss ↑ , Core Loss ↓

(2) Low Total Loss Core Design

Design Area	No. of Turns	Core Perm. (Same Material)	DCB Characteristics (Different Material)
Area 1	Increase	Lower	Lower
Area 2	Decrease	Higher	Higher

Thank You !