SAPHIRE : 233 - Conversion d'énergie
Projet de dimensionnement

29 janvier 2019

Objectif

L'objectif est le dimensionnement via la minimisation de la masse totale et des pertes (Joule et Fer) d'une inductance de puissance dont la géométrie est définie par la figure 1.

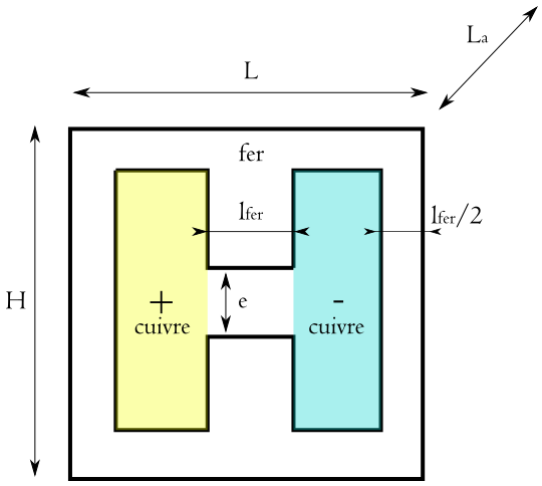


FIGURE 1 – Représentation schématique d'une inductance (L_a représente la longueur dans la partie 3D)

Cette inductance aura les caractéristiques suivantes :
— Une énergie stockée de $4\,J$
— Un courant maximal de $20\,A$
— Une densité de courant maximale de $5\,10^6\,A.m^{-2}$ (dans le cas où aucun modèle thermique est considéré)
— Un volume externe maximal de $1,31\,10^{-3}\,m^3$
— La fréquence d'utilisation $f = 50\,Hz$

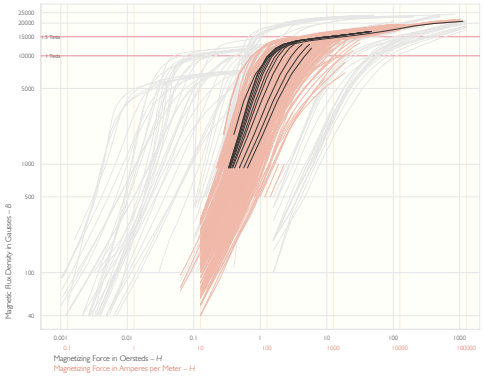
Données techniques des matériaux

Les matériaux utilisées seront le cuivre et du fer silicium 3% :
— Masse volumique du fer silicium : $7874\,kg.m^{-3}$
— Masse volumique du cuivre : $8960\,kg.m^{-3}$
— Conductivité électrique du cuivre : $59,6\,10^6 S.m^{-1}$
— Un coefficient de bobinage : $k_b = 0,4$

Données techniques magnétiques du matériau magnétique

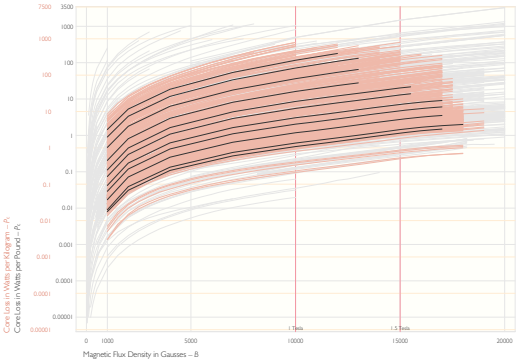
Summary Graphs

Magnetization – *B* vs. *H*



Magnetization curves for this material, DC through 2000 hertz
All non-oriented silicon steels
All other materials

Total Core Loss – P_c vs. *B*



Total core loss curves for this material, 50 through 2000 hertz
All non-oriented silicon steels
All other materials

Summary magnetization and total core loss curves for as-sheared .014 inch (.36 mm, 29 gauge) Di-Max M-19 fully processed cold-rolled non-oriented silicon steel showing their relation to these properties for other materials found in *Lamination Steels Third Edition*. See the following pages for detailed graphs and data values.

Producer: AK Steel, Middletown, Ohio, USA, www.aksteel.com.

Primary standard: ASTM A677 36F155.

Information on this page is not guaranteed or endorsed by The Electric Motor Education and Research Foundation. Confirm material properties with material producer prior to use.

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Sprague, Steve, editor. 2007. Lamination Steels Third Edition, A Compendium of Lamination Steel Alloys Commonly Used in Electric Motors. South Dartmouth, Massachusetts: The Electric Motor Education and Research Foundation. CD-ROM. Non-Oriented Silicon Steels: AK Steel Di-Max M-19, Fully Processed, .014 inch (.36 mm, 29 gauge), MIT OCW Excerpts.

Lamination Steels Third Edition is © 2007 by the Electric Motor Education and Research Foundation; ISBN 0971439125. Information about the complete CD-ROM can obtained from:

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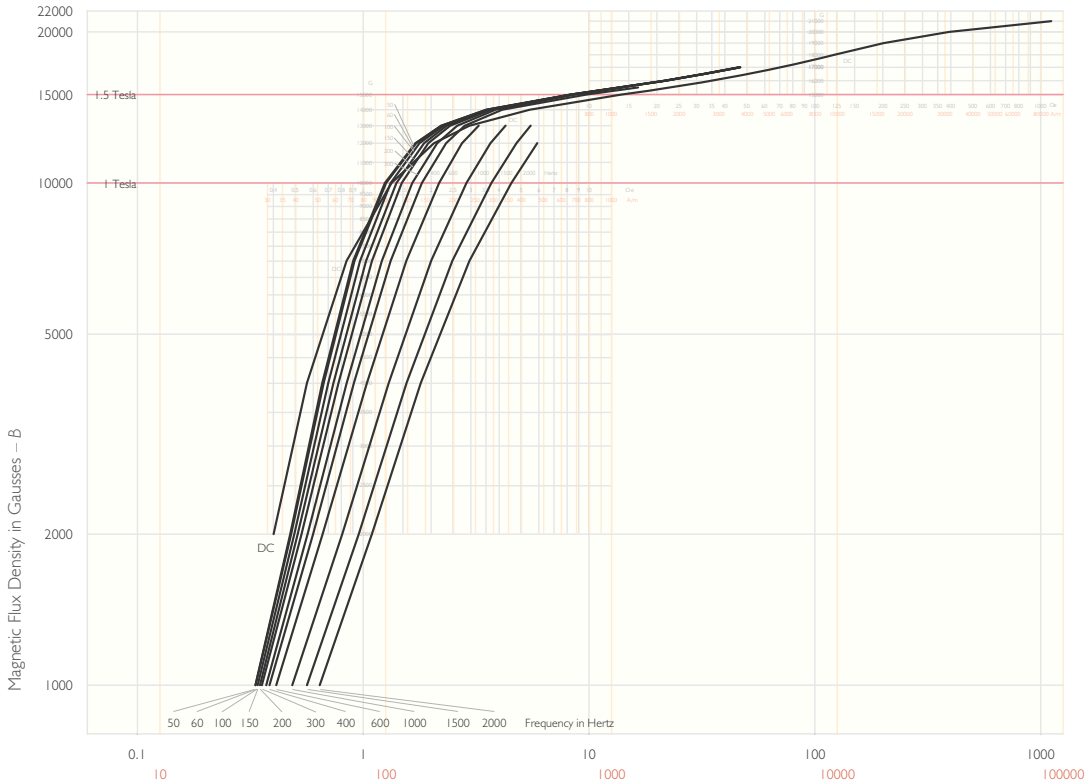
AK Steel
Di-Max M-19
Fully Processed
.014 inch
(.36 mm, 29 gauge)

EMERF
LSTE

Magnetization – *B* vs. *H* – by Frequency



Typical DC and derived AC magnetizing force of as-sheared .014 inch (.36 mm, 29 gauge) Di-Max M-19 fully processed cold-rolled non-oriented silicon steel. See magnetization data page for data values. DC curve developed from published and AC curves from previously unpublished data for Di-Max M-19 provided by AK Steel, 2000. AC magnetization data derived from exciting power data; see exciting power data page for source data and magnetization data page for conversion information. Chart prepared by EMERF, 2004. Information on this page is not guaranteed or endorsed by The Electric Motor Education and Research Foundation. Confirm material properties with material producer prior to use.

Magnetization – *B* vs. *H*

DC and Derived AC Magnetizing Force in Oersteds and Amperes per Meter at Various Frequencies – *H*

Magnetic Flux Density in Gausses – *B*

	DC		50 Hz		60 Hz		100 Hz		150 Hz		200 Hz		300 Hz		400 Hz		600 Hz		1000 Hz		1500 Hz		2000 Hz	
	Oe	A/m																						
1000			0.333	26.5	0.334	26.6	0.341	27.1	0.349	27.8	0.356	28.3	0.372	29.6	0.385	30.6	0.412	32.8	0.485	38.6	0.564	44.9	0.642	51.1
2000	0.401	31.9	0.475	37.8	0.480	38.2	0.495	39.4	0.513	40.8	0.533	42.4	0.567	45.1	0.599	47.7	0.661	52.6	0.808	64.3	0.955	76.0	1.09	86.9
4000	0.564	44.9	0.659	52.4	0.669	53.2	0.700	55.7	0.739	58.8	0.777	61.8	0.846	67.3	0.911	72.5	1.04	82.8	1.30	103	1.56	124	1.80	143
7000	0.845	67.3	0.904	71.9	0.916	72.9	0.968	77.0	1.03	82.0	1.09	87.1	1.21	96.4	1.33	105	1.55	124	2.00	159	2.48	198	2.95	235
10000	1.34	106	1.25	99.3	1.26	101	1.32	105	1.40	112	1.48	118	1.65	131	1.82	145	2.17	173	2.87	228	3.70	294	4.53	361
12000	2.06	164	1.71	136	1.72	137	1.78	141	1.86	148	1.94	155	2.13	169	2.33	185	2.74	218	3.66	291	4.77	380	5.89	469
13000	2.95	235	2.21	176	2.22	177	2.27	181	2.34	186	2.42	193	2.61	208	2.82	224	3.24	258	4.27	340	5.50	438		
14000	5.47	435	3.51	279	3.51	279	3.57	284	3.63	289	3.69	294	3.86	307	4.13	329								
15000	13.9	1109	8.28	659	8.31	662	8.37	666	8.37	666	8.48	675	8.65	689	9.74	775								
15500	22.8	1813	13.6	1084	13.6	1081	13.8	1095	13.7	1092	13.8	1096	14.1	1122	16.5	1313								
16000	35.2	2802	21.6	1718	21.7	1728	21.8	1735	21.8	1738	21.9	1742												
16500	50.9	4054	32.4	2577	32.5	2587	32.6	2597	32.5	2590	32.6	2594												
17000	70.3	5592	46.1	3670	46.2	3680	46.4	3692	46.6	3712	46.6	3711												
18000	122	9711																						
19000	202	16044																						
20000	394	31319																						
21000	1112	88491																						

Typical DC and derived AC magnetizing force of as-sheared .014 inch (.36 mm, 29 gauge) Di-Max M-19 fully processed cold-rolled non-oriented silicon steel. DC values in Oersteds from published AK Steel documents. AC values in Oersteds developed from previously unpublished exciting power information provided by AK Steel, 2000. AC values have been derived from RMS Exciting Power using the following formulas:

$$\text{Magnetizing Force in Oersteds} = \frac{88.19 \times \text{Density (g/cc)} \times \text{RMS Exciting Power (VA/lb)}}{\text{Magnetic Flux Density (kG)} \times \text{Frequency (Hz)}}$$

Density of M-19 = 7.65 g/cc
Values in Amperes per meter = Oersteds × 79.58

See exciting power data page for AC exciting power source data. Magnetizing force formula developed by AK Steel; use only for deriving magnetizing force of AK Steel non-oriented silicon steel. Data table preparation, including conversion of data values, by EMERF, 2004.

AK Steel
Di-Max M-19
Fully Processed
.014 inch
(.36 mm, 29 gauge)

Core Loss
Curves

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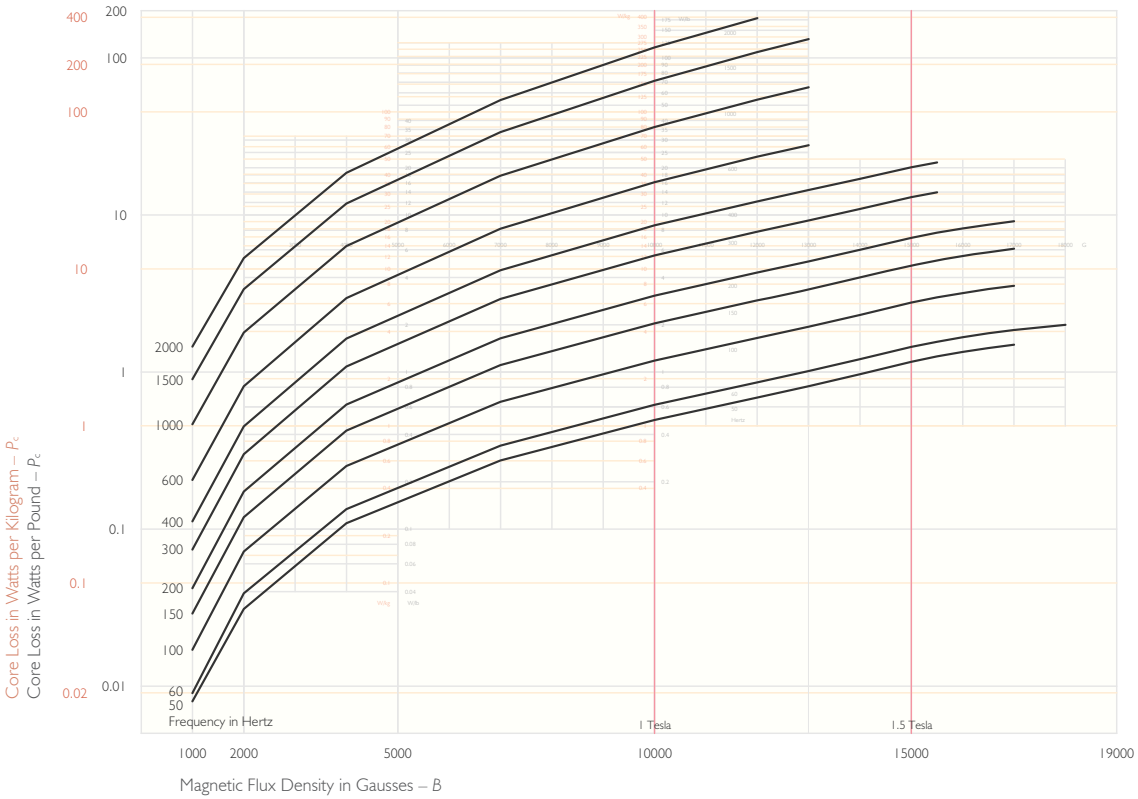
Total Core Loss – P_c vs. B – by Frequency



Typical total AC core loss of as-sheared .014 inch (.36 mm, 29 gauge) Di-Max M-19 fully processed cold-rolled non-oriented silicon steel. See core loss data page for data values. Curves developed from previously unpublished information provided by AK Steel, 2000. Chart prepared by EMERF, 2004.

Total Core Loss – P_c vs. B

Core Loss in Watts per Pound and Watts per Kilogram at Various Frequencies – P_c

W/lb W/kg

Magnetic Flux Density in Gausses – B	50 Hz	60 Hz	100 Hz	150 Hz	200 Hz	300 Hz	400 Hz	600 Hz	1000 Hz	1500 Hz	2000 Hz
1000	0.008 0.0176	0.009 0.0198	0.017 0.0375	0.029 0.0639	0.042 0.0926	0.074 0.163	0.112 0.247	0.205 0.452	0.465 1.02	0.9 1.98	1.45 3.20
2000	0.031 0.0683	0.039 0.0860	0.072 0.159	0.119 0.262	0.173 0.381	0.300 0.661	0.451 0.994	0.812 1.79	1.79 3.94	3.37 7.43	5.32 11.7
4000	0.109 0.240	0.134 0.295	0.252 0.555	0.424 0.934	0.621 1.37	1.09 2.39	1.64 3.60	2.96 6.52	6.34 14.0	11.8 26.1	18.5 40.8
7000	0.273 0.602	0.340 0.749	0.647 1.43	1.11 2.44	1.64 3.61	2.92 6.44	4.45 9.81	8.18 18.0	17.8 39.1	33.7 74.3	54.0 119
10000	0.494 1.09	0.617 1.36	1.18 2.61	2.04 4.50	3.06 6.74	5.53 12.2	8.59 18.9	16.2 35.7	36.3 80.0	71.5 158	117 257
12000	0.687 1.51	0.858 1.89	1.65 3.63	2.86 6.30	4.29 9.46	7.83 17.3	12.2 26.9	23.5 51.8	54.3 120	109 240	179 395
13000	0.812 1.79	1.01 2.23	1.94 4.28	3.36 7.41	5.06 11.2	9.23 20.3	14.4 31.8	27.8 61.3	65.1 143	132 291	
14000	0.969 2.14	1.21 2.66	2.31 5.09	4.00 8.82	6.00 13.2	10.9 24.1	17.0 37.5				
15000	1.16 2.56	1.45 3.19	2.77 6.11	4.76 10.5	7.15 15.8	13.0 28.7	20.1 44.4				
15500	1.26 2.77	1.56 3.44	2.99 6.59	5.15 11.4	7.71 17.0	13.9 30.7	21.6 47.6				
16000	1.34 2.96	1.67 3.67	3.18 7.01	5.47 12.0	8.19 18.0						
16500	1.42 3.13	1.76 3.89	3.38 7.44	5.79 12.8	8.67 19.1						
17000	1.49 3.29	1.85 4.08	3.54 7.80	6.09 13.4	9.13 20.1						
18000		2.00 4.40									

Typical total AC core loss of as-sheared .014 inch (.36 mm, 29 gauge) Di-Max M-19 fully processed cold-rolled non-oriented silicon steel. Watts per pound values from previously unpublished information provided by AK Steel, 2000. Data table preparation, including conversion of data values, by EMERF, 2004.

Watts per kilogram values developed using this formula: Watts per Kilogram = Watts per Pound × 2.204 .

AK Steel
Di-Max M-19
Fully Processed
.014 inch
(.36 mm, 29 gauge)

Exciting Power

Exciting Power in Volt-amps per Pound and Volt-amps per Kilogram at Various Frequencies

V-A/lb V-A/kg

Magnetic Flux Density in Gausses – B	50 Hz	60 Hz	100 Hz	150 Hz	200 Hz	300 Hz	400 Hz	600 Hz	1000 Hz	1500 Hz	2000 Hz
1000	0.025 0.055	0.030 0.066	0.051 0.112	0.078 0.172	0.106 0.234	0.165 0.364	0.228 0.503	0.366 0.807	0.719 1.58	1.25 2.76	1.90 4.20
2000	0.07 0.154	0.085 0.187	0.147 0.324	0.228 0.503	0.316 0.696	0.504 1.11	0.710 1.56	1.18 2.59	2.40 5.28	4.25 9.36	6.48 14.3
4000	0.195 0.430	0.238 0.525	0.415 0.915	0.657 1.45	0.921 2.03	1.51 3.32	2.16 4.76	3.70 8.15	7.70 17.0	13.9 30.5	21.4 47.1
7000	0.469 1.03	0.57 1.26	1.00 2.21	1.60 3.53	2.27 5.00	3.77 8.31	5.50 12.1	9.67 21.3	20.8 45.7	38.7 85.2	61.3 135
10000	0.925 2.04	1.12 2.48	1.96 4.32	3.12 6.88	4.39 9.68	7.33 16.2	10.8 23.8	19.3 42.5	42.5 93.7	82.2 181	134 296
12000	1.52 3.34	1.83 4.04	3.16 6.96	4.96 10.9	6.91 15.2	11.4 25.0	16.6 36.5	29.2 64.4	65.1 143	127 280	210 462
13000	2.13 4.69	2.57 5.66	4.38 9.65	6.77 14.9	9.34 20.6	15.1 33.2	21.7 47.8	37.5 82.7	82.3 181	159 350	
14000	3.64 8.02	4.37 9.63	7.41 16.3	11.3 24.9	15.3 33.8	24.0 52.9	34.3 75.6				
15000	9.20 20.3	11.1 24.4	18.6 41.0	27.9 61.5	37.7 83.1	57.7 127	86.6 191				
15500	15.6 34.5	18.7 41.3	31.6 69.6	47.3 104	63.3 140	97.2 214	152 334				
16000	25.6 56.4	30.9 68.1	51.7 114	77.7 171	104 229						
16500	39.6 87.3	47.7 105	79.8 176	119 263	159 351						
17000	58.1 128	69.9 154	117 258	176 389	235 518						

Typical RMS Exciting Power of as-sheared .014 inch (.36 mm, 29 gauge) Di-Max M-19 fully processed cold-rolled non-oriented silicon steel. Volt-amps per pound values from previously unpublished information provided by AK Steel, 2000. Data table preparation, including conversion of data values, by EMERF, 2004.

Volt-amps per kilogram developed using this formula: Volt-amps per kilogram = Volt-amps per pound × 2.204 .