NCSX: INDUCTANCE CALCULATION of MODULAR COILS
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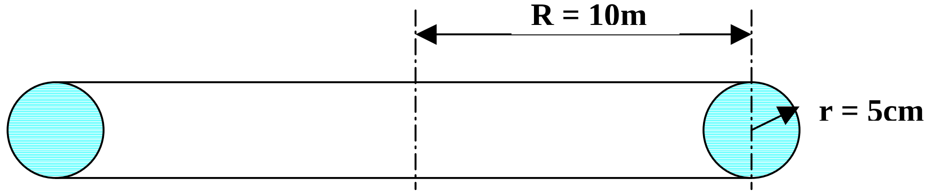
A code is written with Fortran90 to evaluate Inductance.
(/u/cjun/NCSX_INDUCT/ModuIND.f90)

The code is verified by comparing analytic solution.

Comparison 1)
Self inductance calculation of a circular coil with circular section.



Analytic Solution: $L = \mu_o * R * [\ln(8R/r) - 2 + 0.25]$ Henry (When R>r)
(p.158, Silvester & p.60 Grover)

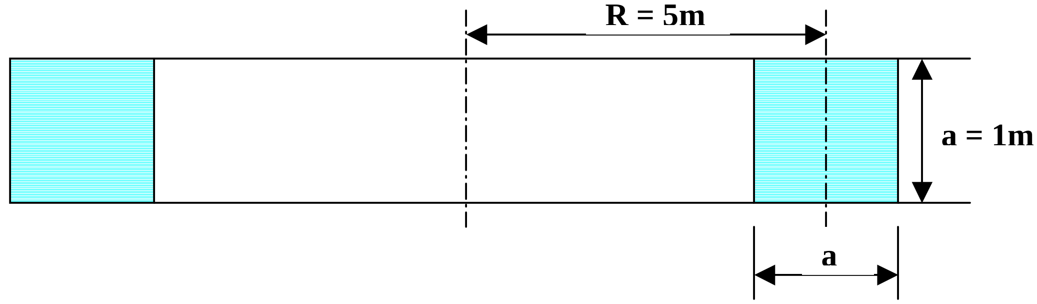
Ex) R = 10m, r = 0.05m (5cm) -> L = 70.72E-6 Henry

Numerical Solution: According to segment length (Section diameter is 10cm)

Case	Segment L.	Results	Analytic	Percent
1	69.8cm(4°)	120.70μH	70.72 μH	170.7%
2	34.9 (2)	85.57	70.72	121.0
3	17.5 (1)	72.34	70.72	102.3
4	8.7 (0.5)	70.12	70.72	99.2
5	4.4 (0.25)	73.33	70.72	103.7
6	2.2 (0.125)	89.39	70.72	126.4

* Numerical solution is very sensitive on mesh sizes:
When (section diameter) = (segment length) -> Best result

Comparison 2)
Self inductance calculation of a circular coil with square section.



Analytic Solution: L = 0.001*P_o*R [μHenry] (When a/(2R) = 0.1, R&a= cm)
(P_o = 31.435: Brooks coil in p.98 Grover)

Ex) R = 500cm, a = 100cm -> L = 15.7175 [μHenry]

Numerical Solution: According to Segment length & Section (Section is divided)

1) **With whole section** (segment side = 100cm, L = 10.0π = 31.416m)

Case	Segment L.	Results	Analytic	Percent
1	157cm(20°)	17.30 μH	15.72 μH	110.1%
2	131 (15)	16.41	15.72	104.4
3	87.3 (10)	16.23	15.72	103.2
4	43.6 (5)	17.84	15.72	113.5

2) **With 2 by 2 section** (segment side = 50cm, L = 10.0π = 31.416m)

Case	Segment L.	Results	Analytic	Percent
1	157cm(20°)	18.11 μH	15.72 μH	115.2%
2	131 (15)	16.66	15.72	106.0
3	87.3 (10)	15.57	15.72	99.0
4	43.6 (5)	15.11	15.72	96.1
5	21.8 (2.5)	15.53	15.72	98.8

3) With 4 by 4 section (segment side = 25cm, L = 10.0π = 31.416m)

Case	Segment L.	Results	Analytic	Percent
1	157cm(20°)	00000 μH	15.72 μH	00000%
2	131 (15)	000000	15.72	00000
3	87.3 (10)	000	15.72	000000
4	43.6 (5)	00000	15.72	00000
5	21.8 (2.5)			
6	10.9 (1.25)			

Comparison 3) NCSX modular coil (section is 127mm x 96.8 mm)

	1 strand case	16strand case (4 by 4)
Geman code	144.18 μH	148.25 μH
My code	147.87 μH	134.70 μH

CONCLUSION)

1) To minimize errors, the NCSX coils has to be divided 4 by 3 instead of 4 by 4. Square shape bears less error than rectangular shape. Circular section shape is ideal to reduce geometric errors.

2) More refined mesh is needed according to longitudinal direction. When segment length has same dimension as a side of section, the numerical solution gives best result.

3) Numerical solution approachs toward analytic one when l/a decreases until $l/a = 1$ (l is segment length and a is section radius or side of segment). If l/a keeps diminishing ($l/a < 1$), the numerical solution increases again and far from analytic solution. The reason is that mutual inductance between neighboring segments becomes greater than the self inductance of segment itself. (Distance between segments will be shorter than segment radius)

4) Acceptable ratio of l/a is proved as ($1 < l/a < 2$).

5) To meet above conditions, more precise examination on coil data generation is necessary. [The END]