Automated designs for low-loss toroidal core components

There is no closed form expression available to evaluate inductance of the toroidal coils wound on a ferrite core. Analytical methods used widely for inductance calculation of toroidal coils yield large errors in the case of sparsely wound coils, especially when using low permeability cores. Hence, to evaluate the electromagnetic efficiency of toroidal core components, Integrated's geometry features proves to be very useful. The toroidal core with a circular cross section is best for obtaining high value of inductance with the least magnetic flux leakage.

To create this schema point-1 was wound on a toroid with an angular pitch of 10° in the software as shown in Fig.1. To generate 21 points on one turn of the wound curve, a circle passing through point-1 and having a center coinciding with that of the toroid cross section was drawn. This circle was divided into 20 equal parts to generate 20 points on it. Point-1 was the starting point of the wound curve. Point-2 was rotated by [10°/(21-1) =] 0.5° about the axis OY to generate the second point-2' on the wound curve. Point-3 by 1°, point-4 by 1.5°, and so on to generate the subsequent points-3', 4',…….,20' on the wound curve. Finally, the last point-1' was generated by rotating the point-1 by 10°. A NURBS curve which forms the first turn of the coil was defined with the points-1, 2', 3', 4',…….., 20', 1'. The first turn was then rotated progressively in increments of 10° about OY axis and copied to produce the other turns.

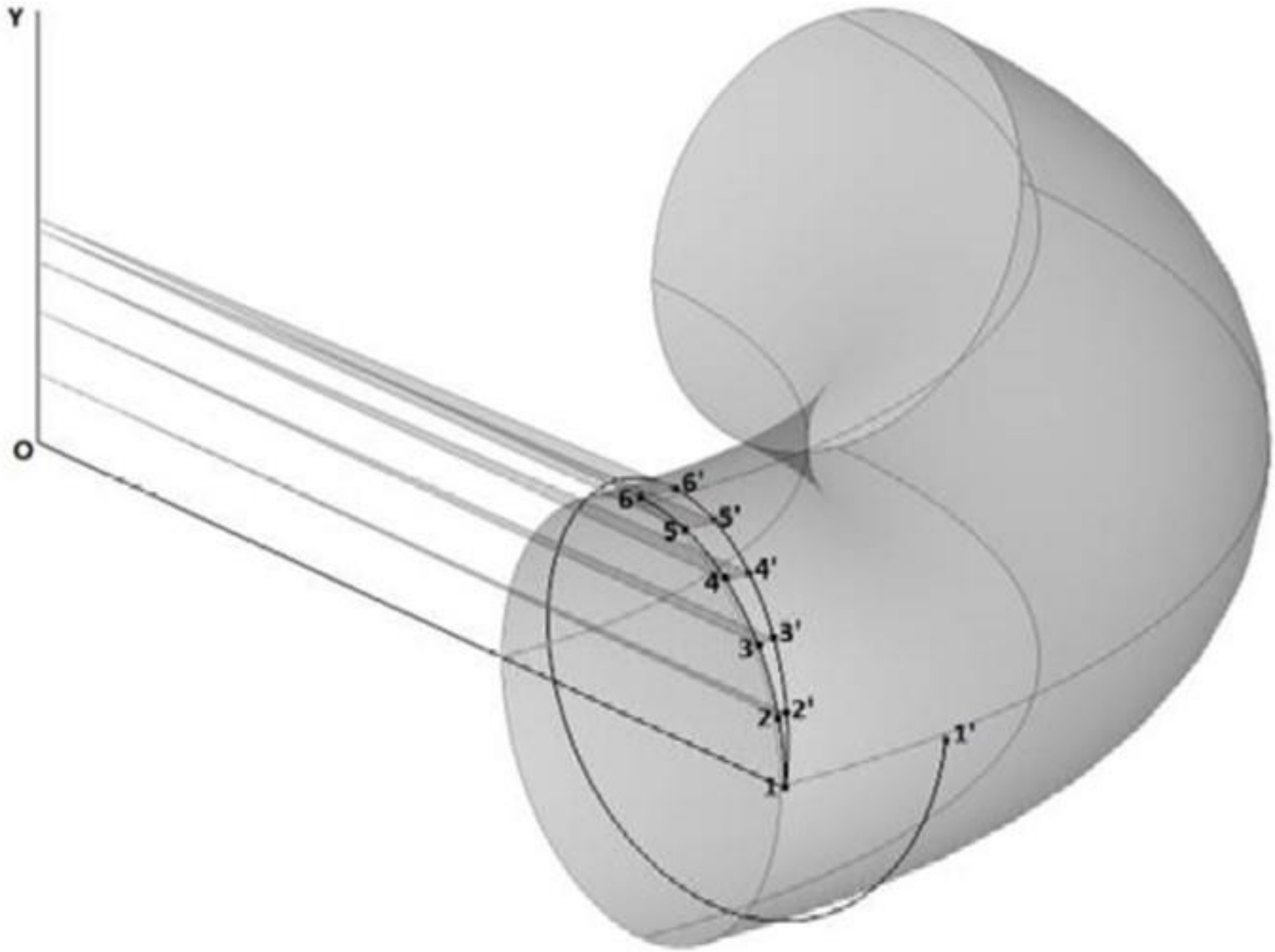

Fig. 1: Winding a point on a toroid

A similar procedure was implemented to generate the two spiraled edges of the strip (surface) wound on a toroid. The ends of the two spiraled edges were connected by two NURBS curves which specified the width of the strip. Using these four edge-segments a Coons surface which represented the first turn was defined. It was observed that the accuracy of the geometry of the spiraled strip could be increased by defining one piece of strip for every 90° in the cases where angular pitch was less than 10°. For larger angular pitches, the number of pieces for one turn of the spiraled strip was increased. This procedure is extended to define the volume coil. The inductance of a toroidal coil was calculated using the Boundary Element Method (BEM). No approximations were assumed in the estimation of the magnetic flux density in this method, hence this method worked for loosely wound and tightly wound coils. A set of sample cases shown in Figs. 2, 3, and 4 are considered to demonstrate the efficacy of the method.

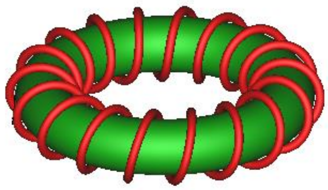

Fig. 2: Mean Radius of Toroid =13mm, Radius of Toroid cross section = 3mm, Wire Radius = 0.5mm, Number of Turns = N = 18, Gap between Wire and Toroid = 0.1mm, Relative permeability of Toroid – μ_r

TABLE-1: Inductance of the coil shown in Fig. 2

Toroid relative permeability(μ_r)	Inductance (micro H)
1	0.280
10	1.582
100	14.282
1000	127.853

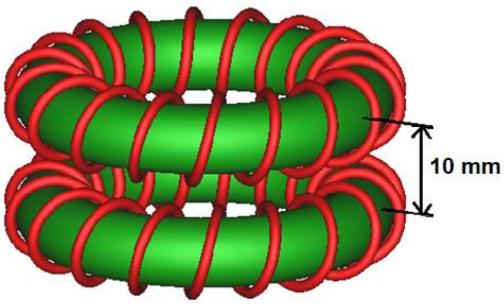

Fig. 3: Two identical coils of specs given in Fig. 2 are placed axially one above the other.

TABLE-2: Inductances of coils shown in Fig. 3

μ_r	Self-Inductance (micro H)	Mutual Inductance (Nano H)
1	0.280	9.67
10	1.583	11.28
100	14.284	10.539
1000	127.862	89.149

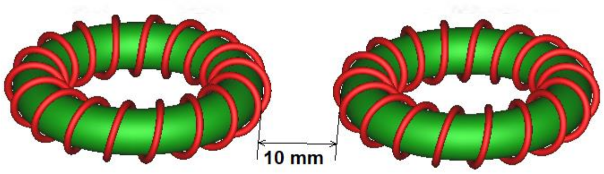

Fig. 4: Two identical coils of specs given in Fig. 2 are placed side by side.

TABLE-3: Inductances of coils shown in Fig. 4

μ_r	Self-Inductance (micro H)	Mutual Inductance (Nano H)
1	0.280	0.5360
10	1.582	0.6925
100	14.284	0.6698
1000	127.862	5.1681

Results show that the effect of the presence of the other coil on the self-inductance value is negligible, which is the main purpose of using closed loop magnetic cores for the inductors. Also, we can notice the mutual inductance between the two coils is very small compared to the self-inductance value. As the relative permeability of the core increases, mutual inductance decreases as compared to the self-inductance example.