가우스 X의 헌신

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CONTENTS

CONTENTS

01

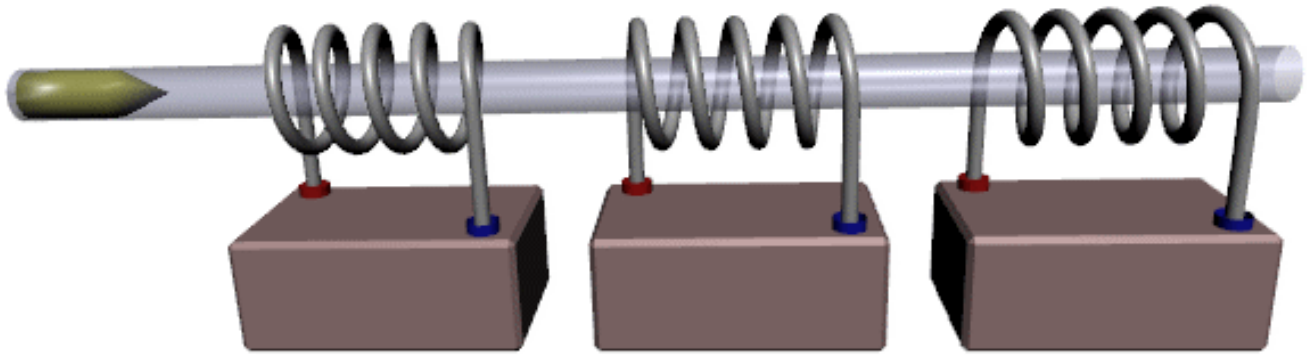
팀 명 선 정 배 경

01. 팀명선정배경

가우스X의 헌신

01. 팀명선정배경

가우스X의 헌신

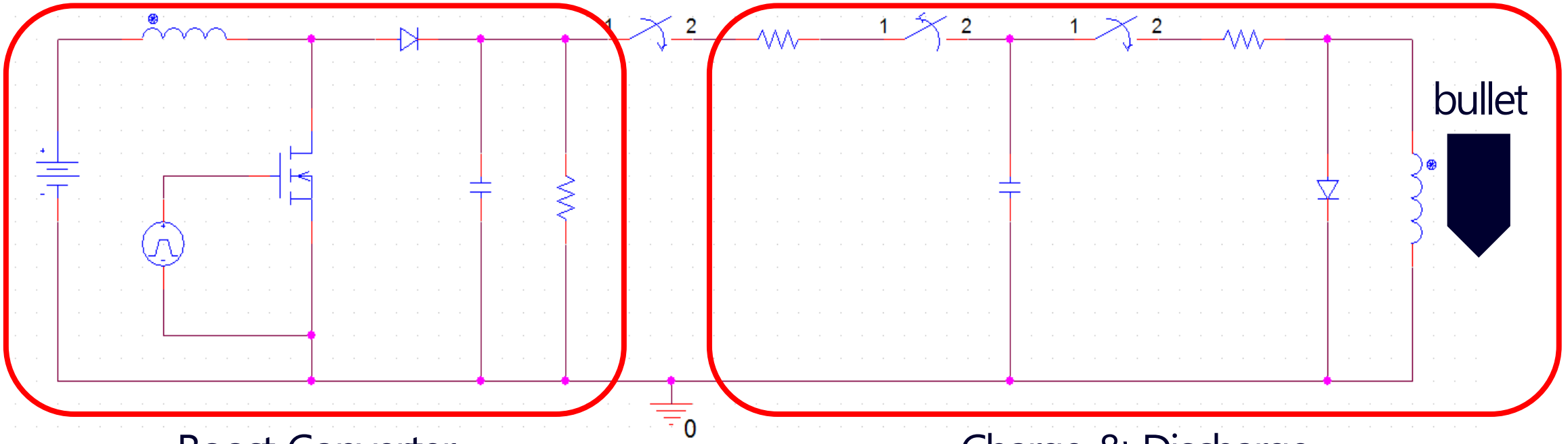


02

회로설계

02. 회로설계

개요



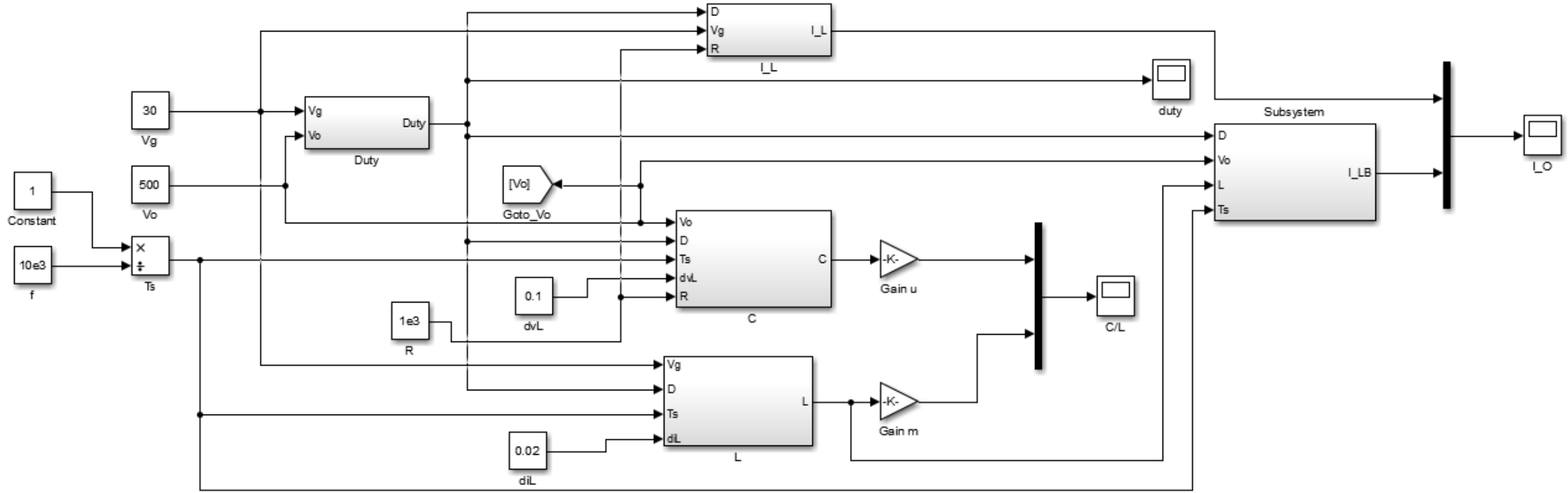
Boost Converter

Charge & Discharge

Coilgun Circuit

02. 회로설계

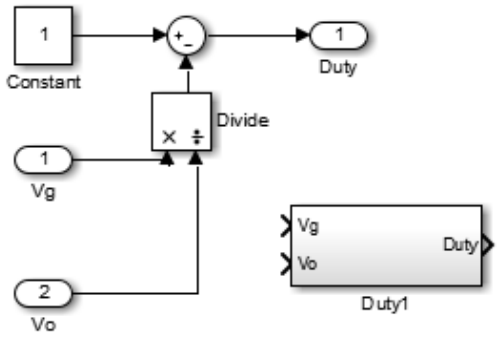
simulink

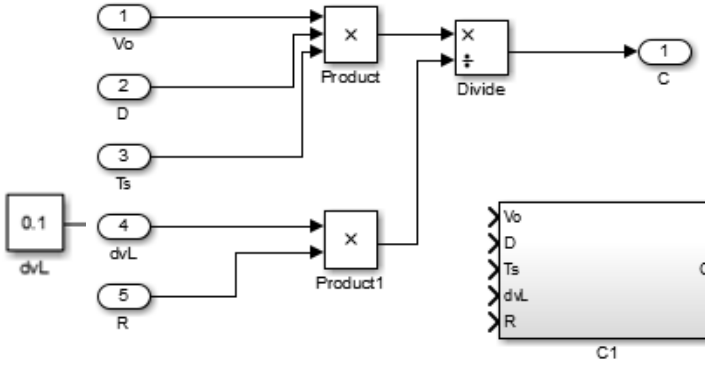


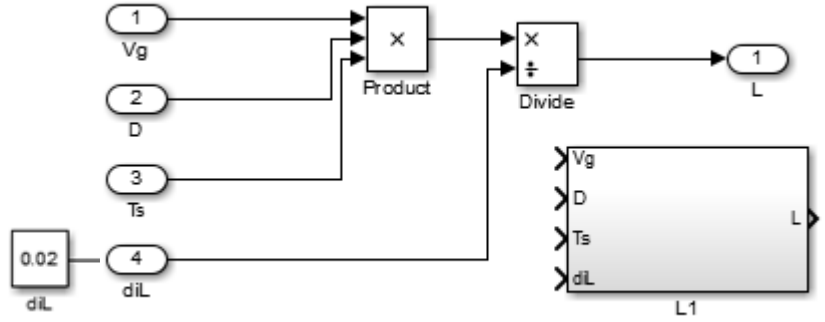
Boost converter

02. 회로설계

simulink

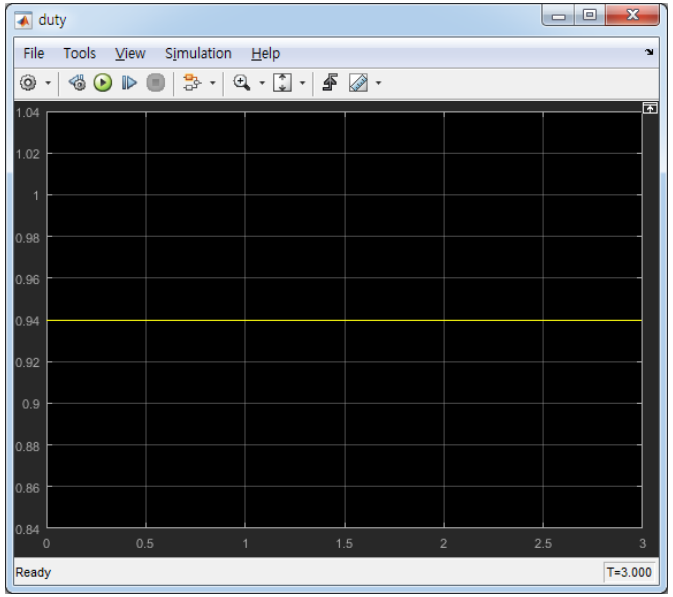




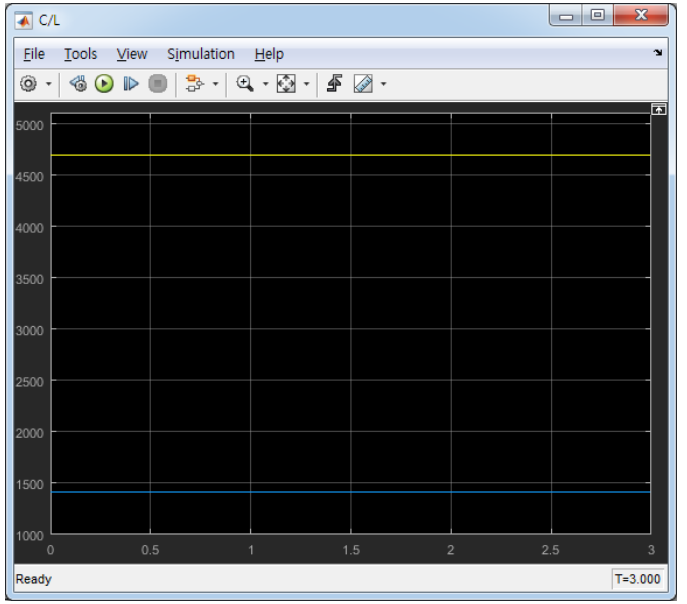


Duty cycle 결정

Ripple 값에 따른 C,L 결정



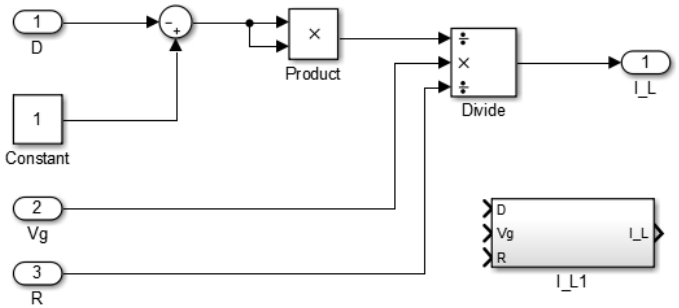
Duty=0.94



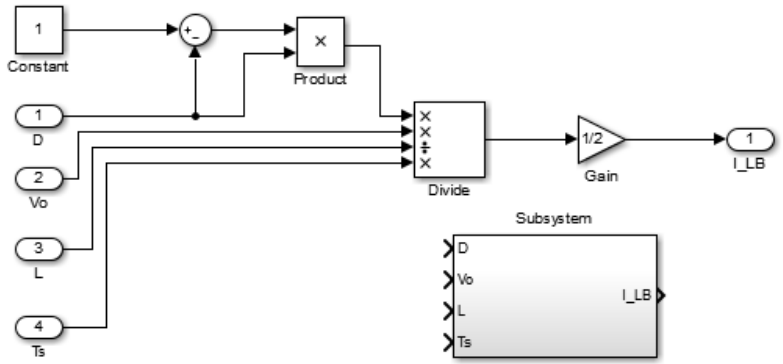
C=4600uF
L=1410mH

02. 회로설계

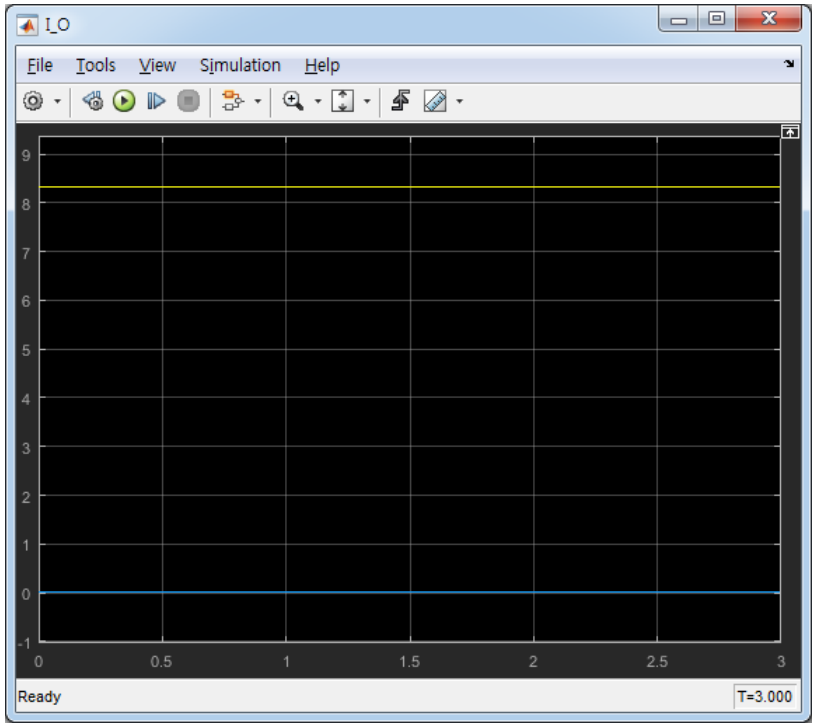
simulink



L에 흐르는 전류



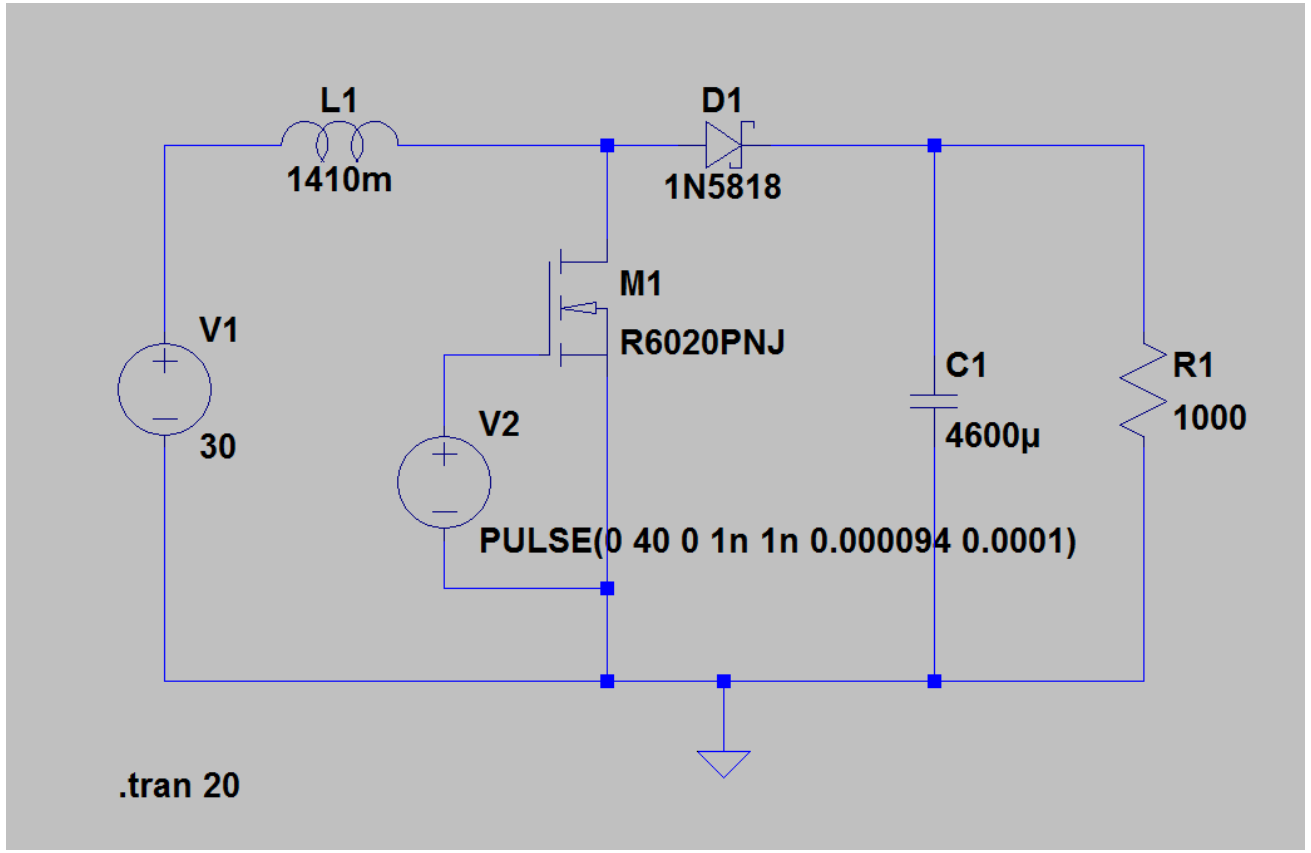
전류의 경계조건



I_L > I_LB
=> continuous

02. 회로설계

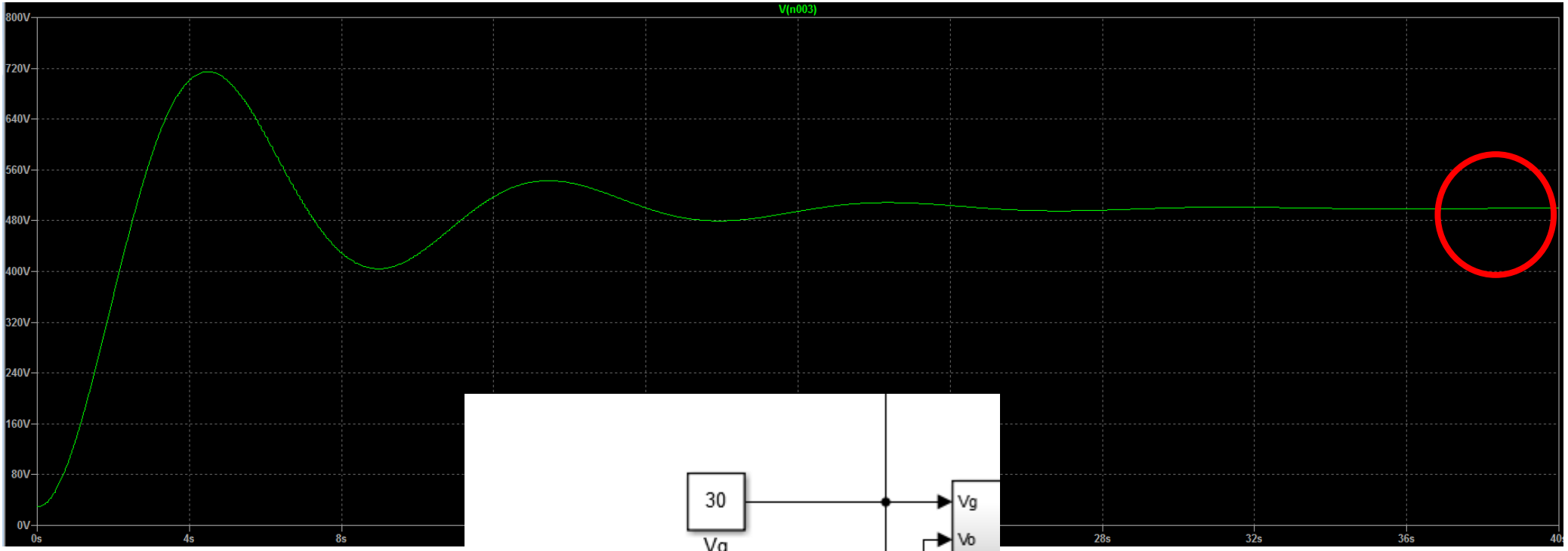
LTspice

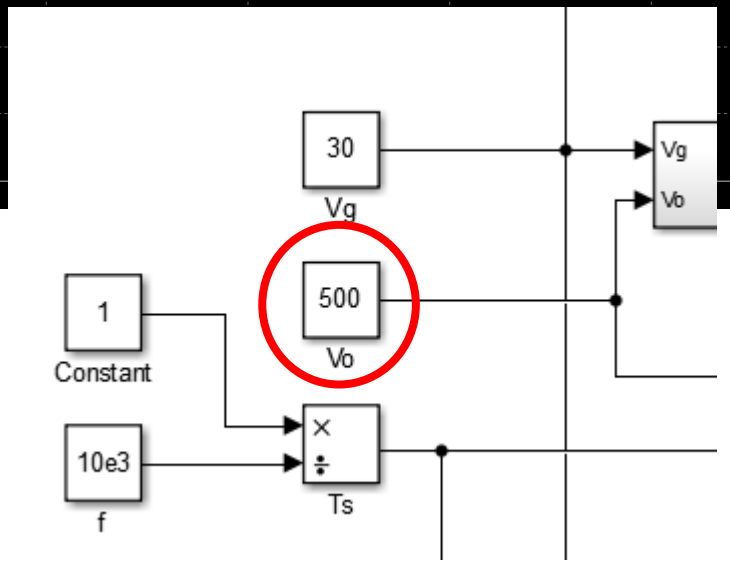


Boost converter

02. 회로설계

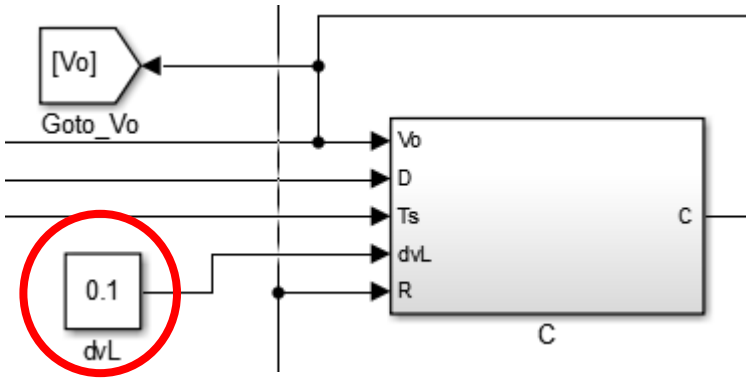
LTspice

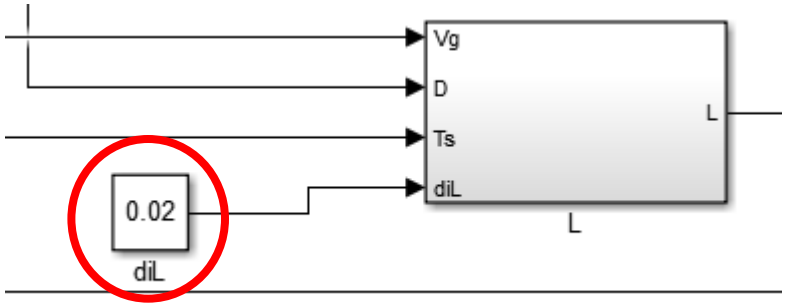


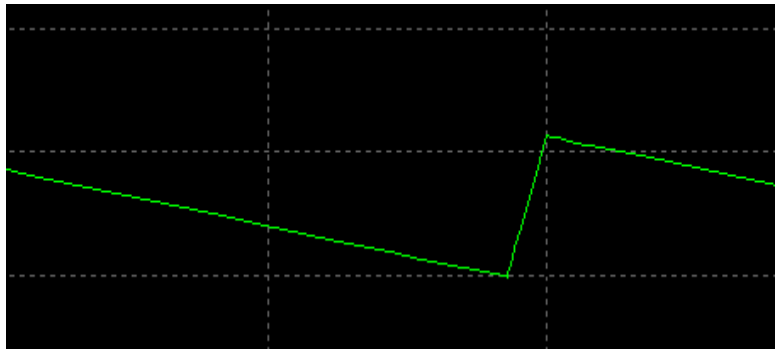


02. 회로설계

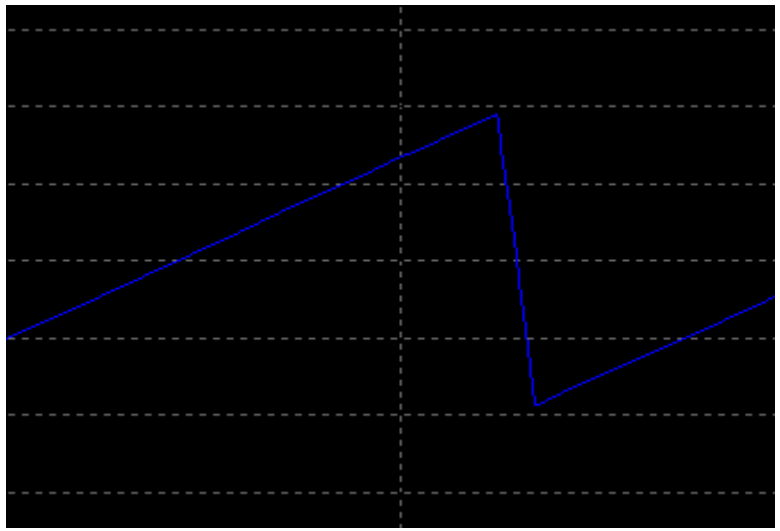
Simulink







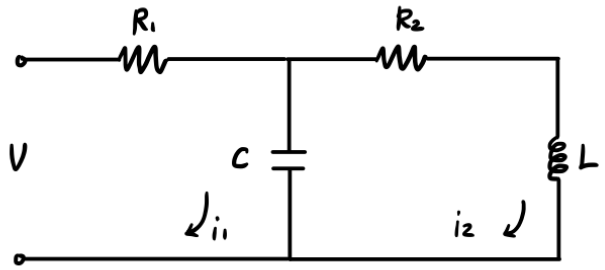
V_ripple=109 mV



I_ripple=19 mA

02. 회로설계

Analytically



$q_1(0)=0,\ \dot{q}_1(0)=0$

$q_2(0)=V/C,\ \dot{q}_2=0$

(1) 충전 회로

키르히호프 법칙을 쓰면

$$V-R_1 i_1(t)-\int \frac{1}{C} i_1(t)\,dt=0$$

$$\Rightarrow V-R_1\frac{dq_1(t)}{dt}-\int \frac{1}{C}\frac{dq_1(t)}{dt}\cdot dt=0$$

$$q_1(t)=CV\left[1-e^{-\frac{1}{R_1C}t}\right]$$

$$i_1(t)=\frac{dq_1(t)}{dt}=\frac{V}{R_1}e^{-\frac{1}{R_1C}t}=\frac{V}{R_1}e^{-\frac{1}{R_1C}t}$$

$$v_1(t)=\frac{q}{C}=V\left[1-e^{-\frac{1}{R_1C}t}\right]$$

(2) 방전 회로

$$v_2(t)+Ri_2(t)+L\frac{di_2(t)}{dt}=0$$

$$\Rightarrow \frac{q_2}{C}(t)+R_2\frac{dq_2(t)}{dt}+L\frac{d^2q_2(t)}{dt}=0$$

Let $A=\frac{R_2}{2L}$, $B=\sqrt{\frac{1}{LC}-\frac{R_2^2}{4L^2}}$

$$q_2(t)=\frac{1}{L}\left[\frac{R_2CV}{B}\cdot\sin Bt\cdot e^{-At}+LCV\cos Bt\cdot e^{-At}\right]$$

$$i_2(t)=\frac{1}{L}\left[\frac{R_2CV}{B}(B\cos Bt\cdot e^{-At}-A\sin Bt\cdot e^{-At})\right.$$

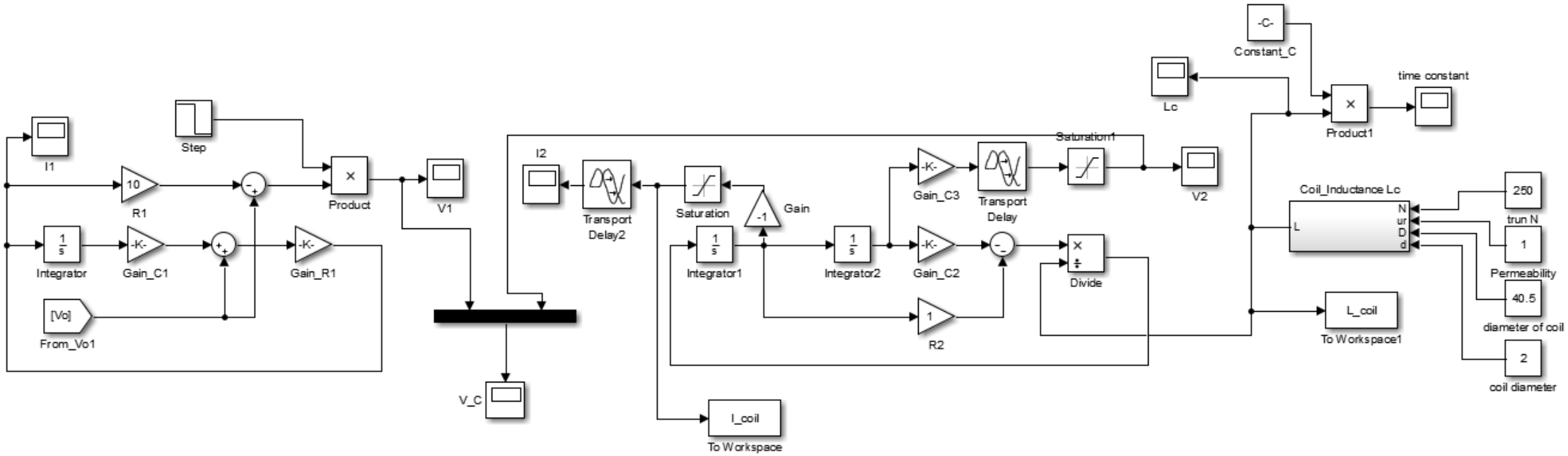
$$\left.+LCV(-B\sin Bt\cdot e^{-At}-A\cos Bt\cdot e^{-At})\right]$$

$$v_2(t)=\left[\frac{R_2V}{B}\cdot\sin Bt\cdot e^{-At}+LV\cdot\cos Bt\cdot e^{-At}\right]$$

Charge & Discharge circuit

02. 회로설계

Simulink



Charge & Discharge circuit

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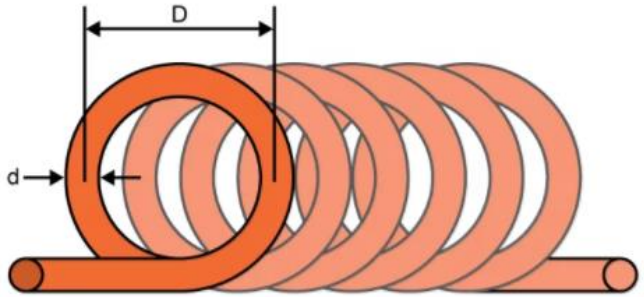
Simulink



Equation

$$L_{coil} \approx N^2 \mu_0 \mu_r \left(\frac{D}{2}\right)\left[ln\left(\frac{8D}{d}\right) - 2\right]$$

Where:

L_{coil} = inductance of the coil in henries (H)

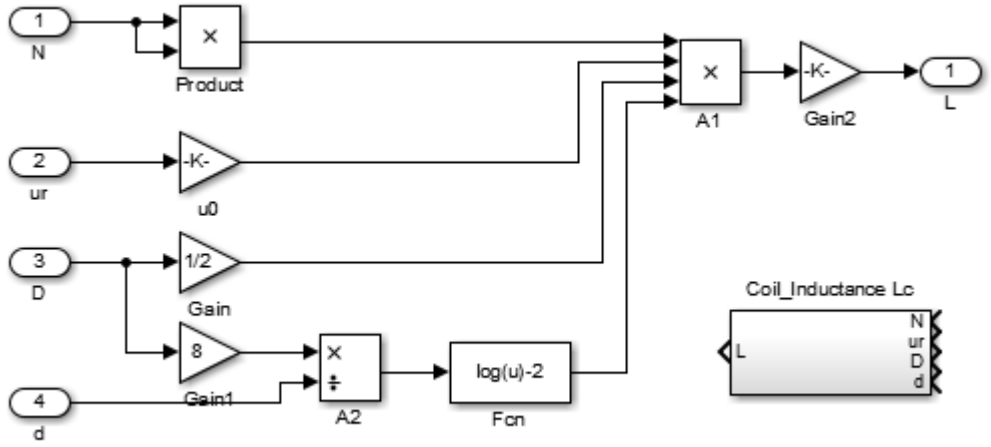
N^2 = number of turns

μ_0 = permeability of free space = $4\pi \times 10^{-7}$

μ_r = relative permeability

D = loop diameter

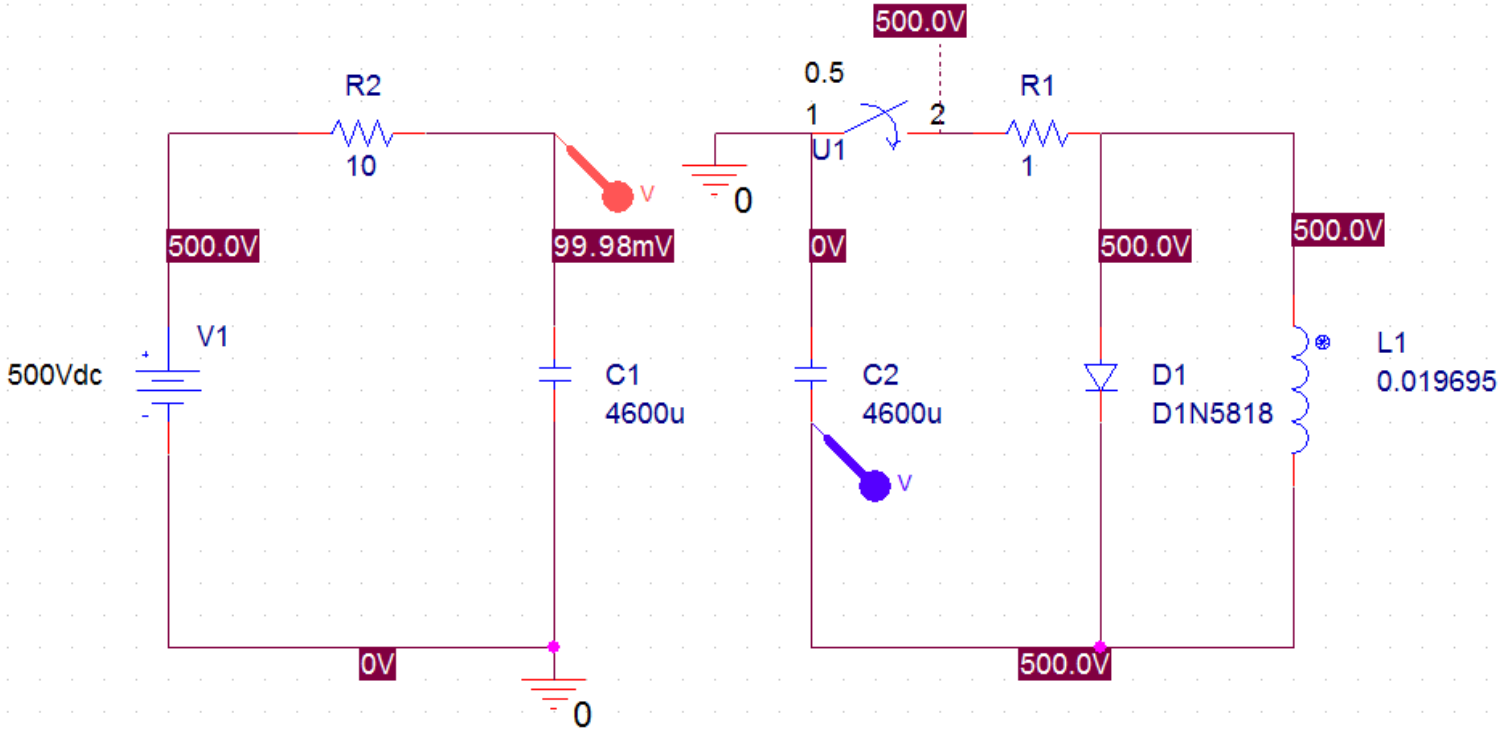
d = wire diameter



코일의 인덕턴스 계산

02. 회로설계

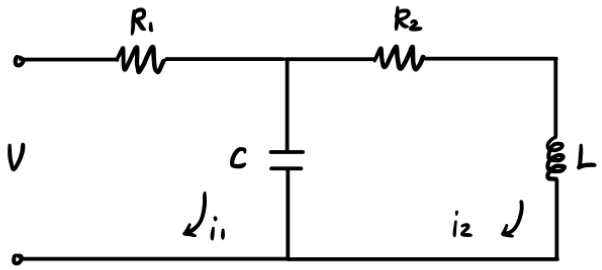
Pspice



Charge & Discharge circuit

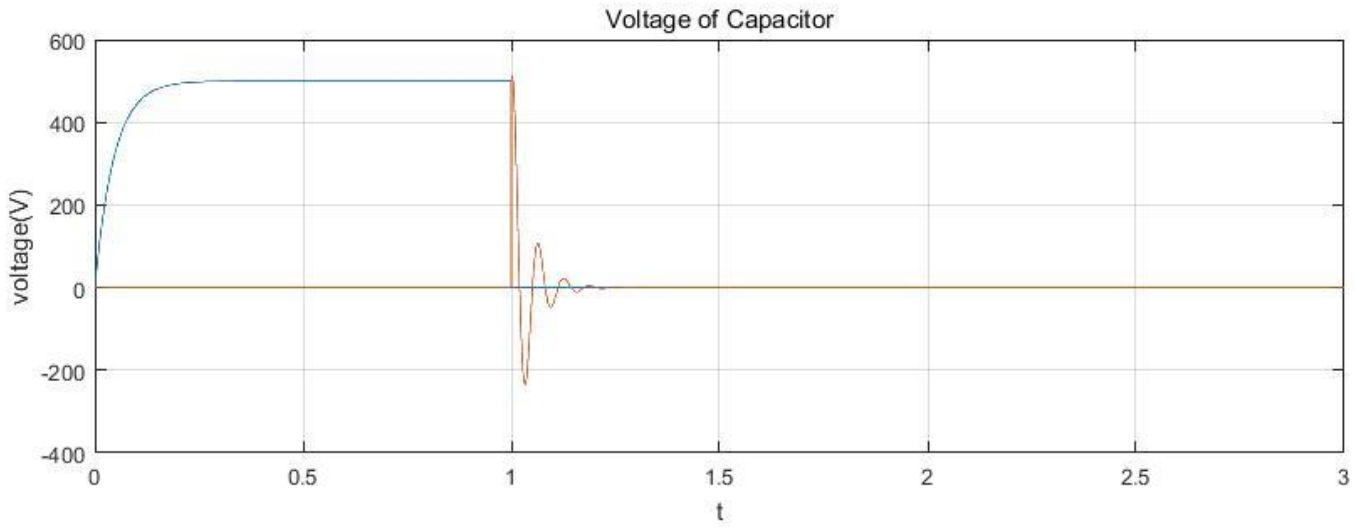
02. 회로설계

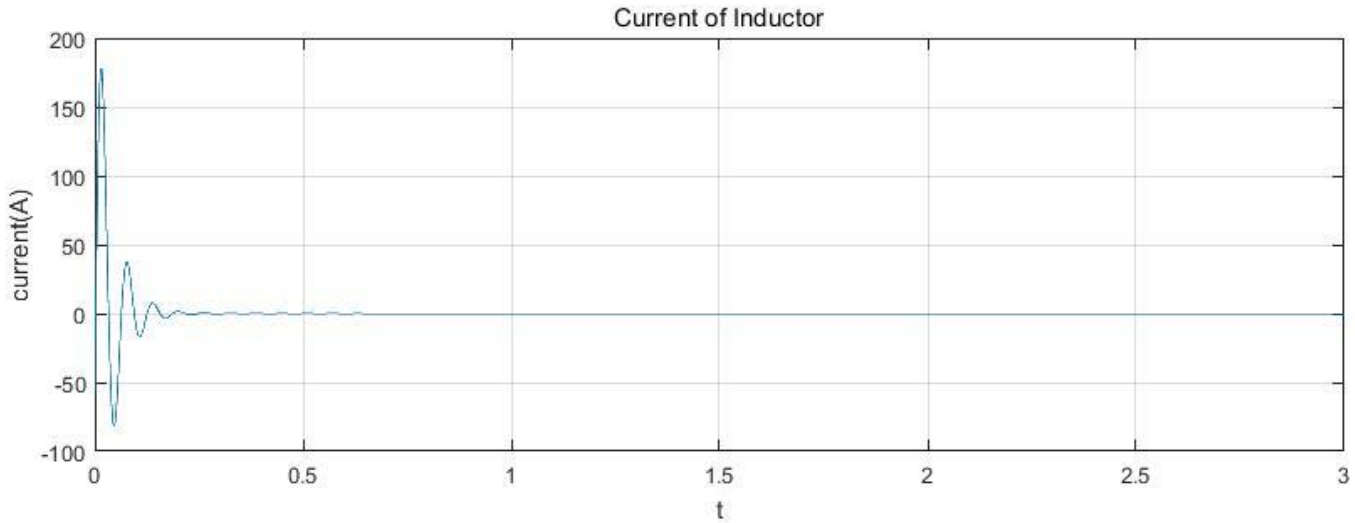
Analytically



$q_1(0) = 0 \;,\; \dot{q}_1(0) = 0$

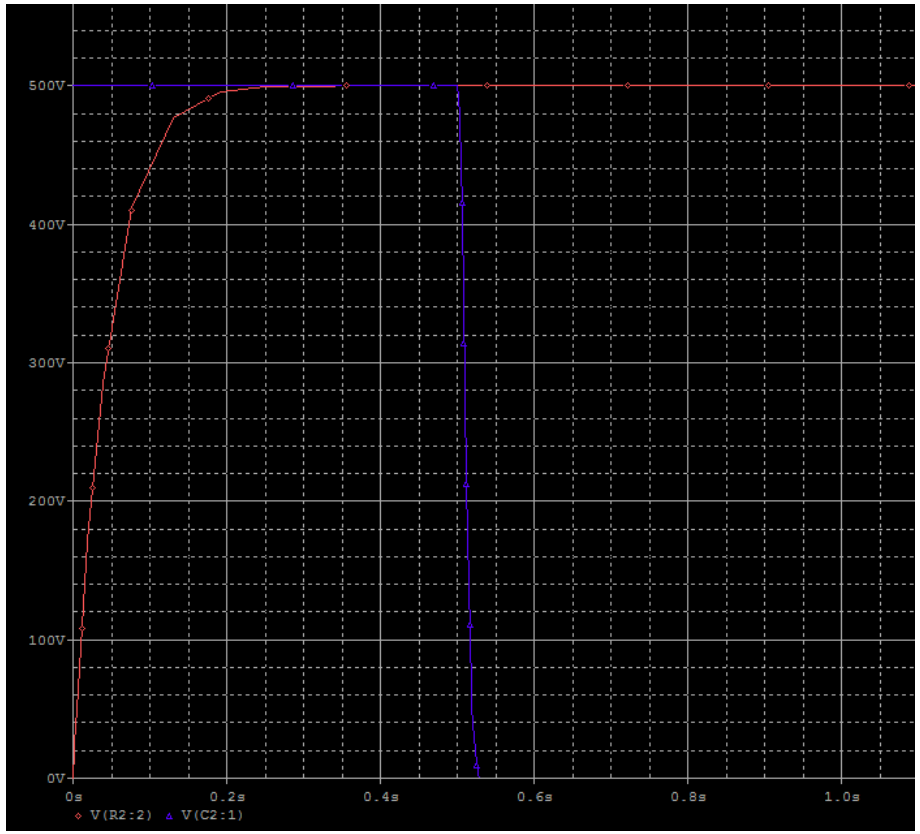
$q_2(0) = V/C \;,\; \dot{q}_2 = 0$



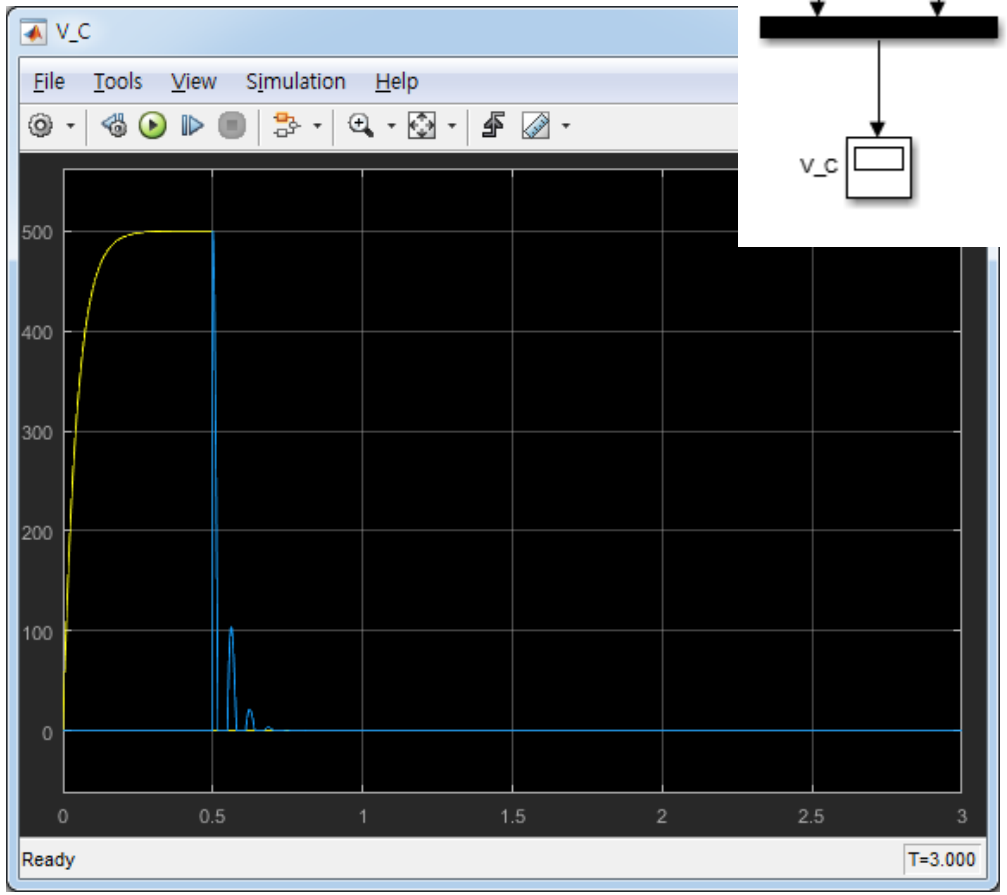


02. 회로설계

Pspice



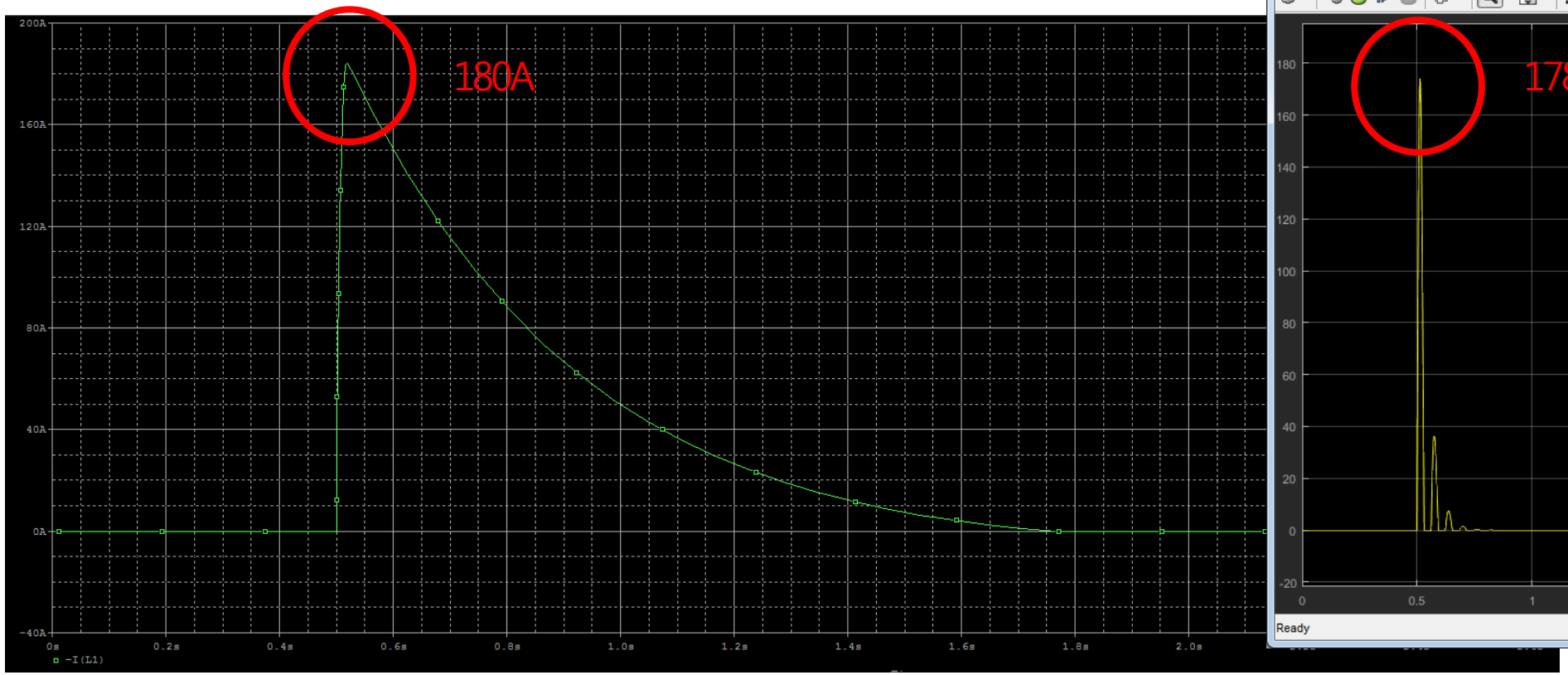
Charge Discharge

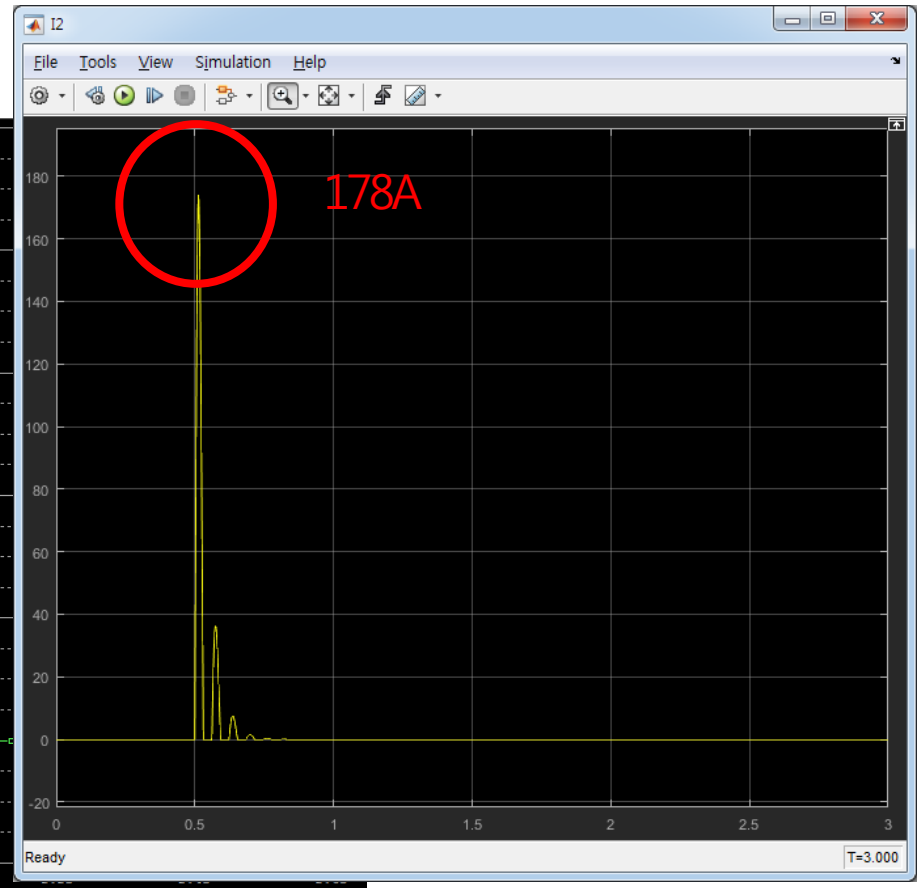


충 방전시 V 비교

02. 회로설계

Pspice





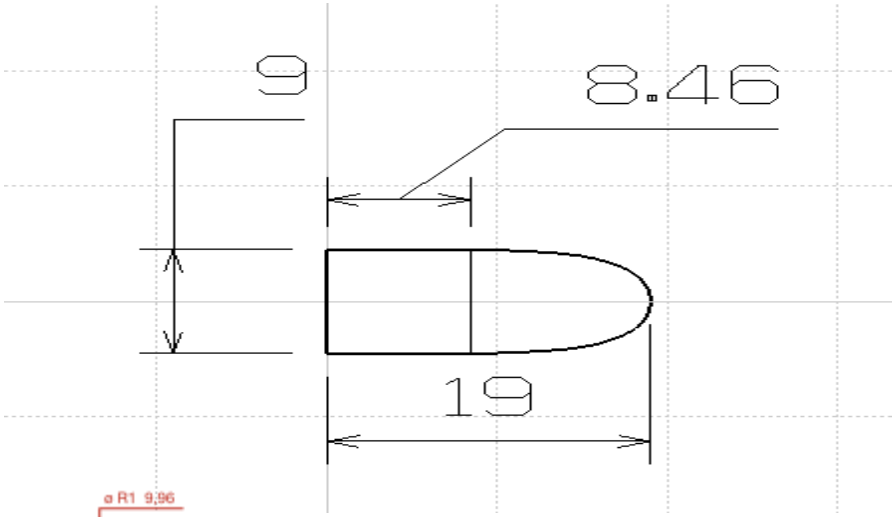
코일에 인가되는 전류 비교

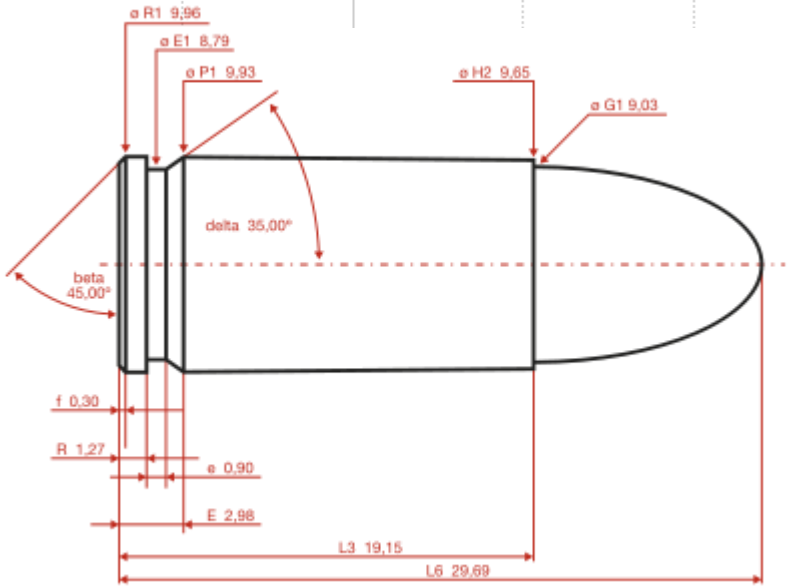
03

코일건 모델링

03.코일건모델링

CATIA



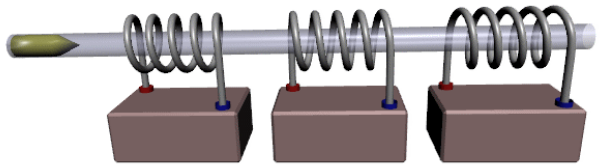


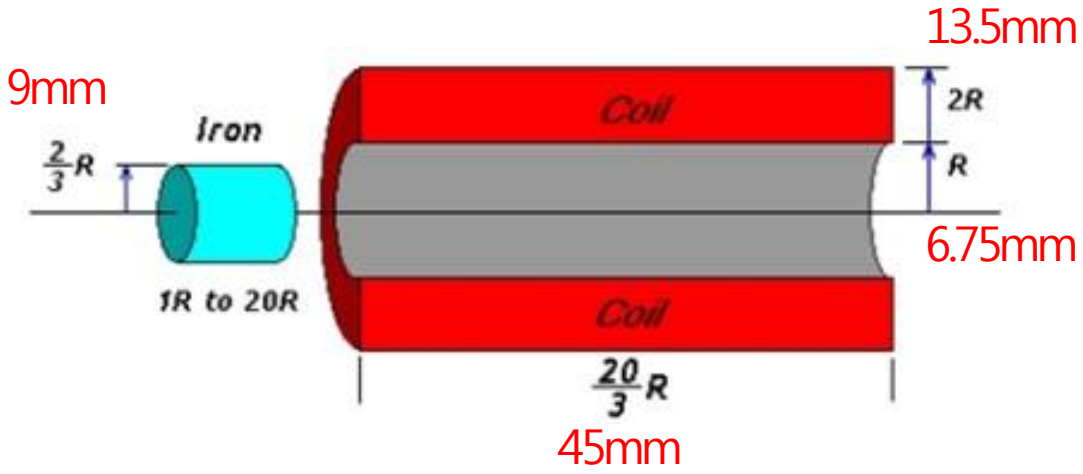
Bullet- Iron

총알 모델링

03.코일건모델링

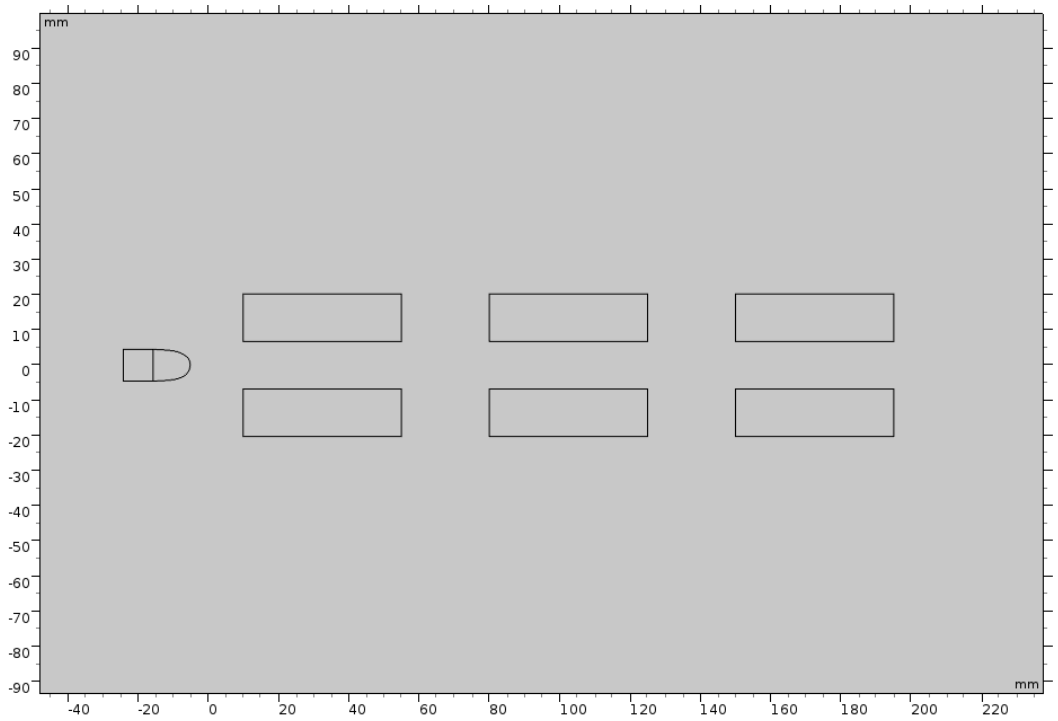
COMSOL





R=27/4

코일건 규격



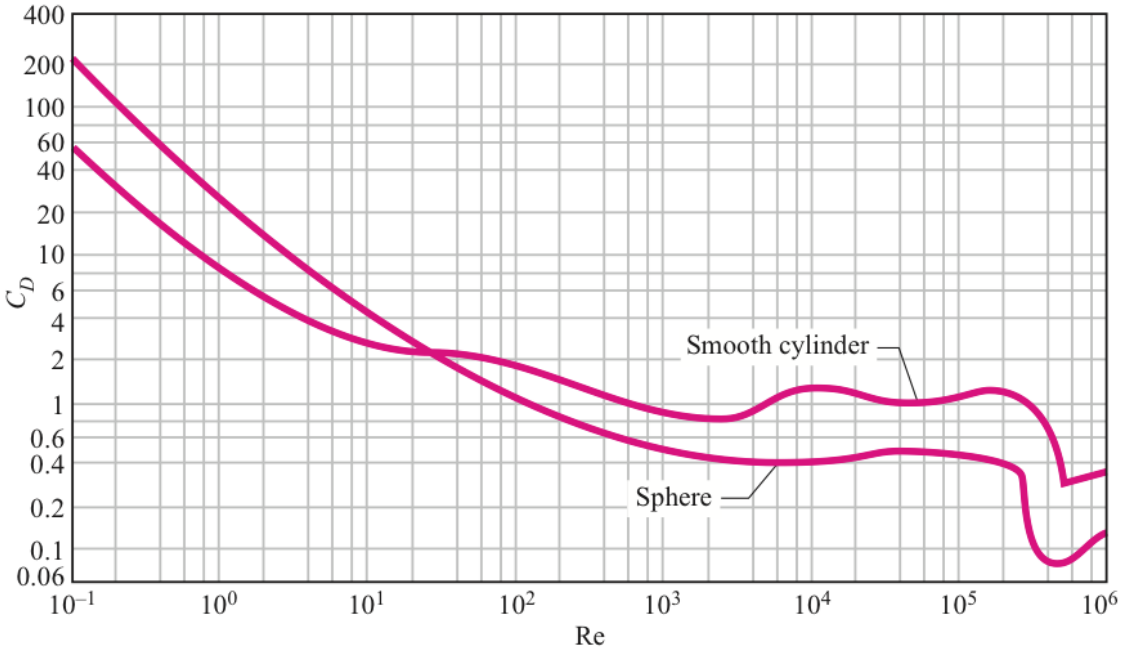
COMSOL 모델링

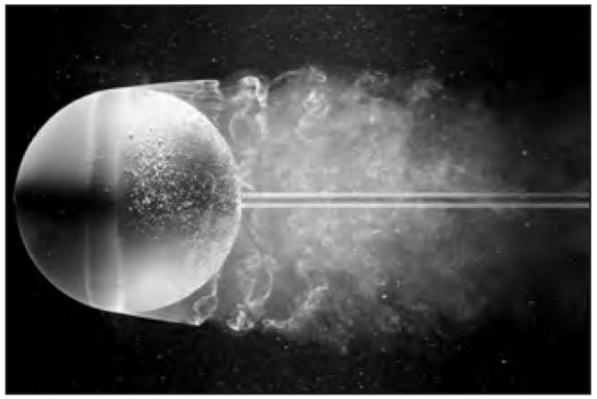
03.코일건모델링

COMSOL

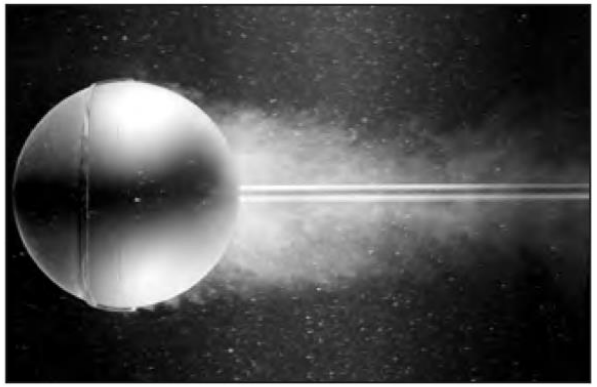
- In the moderate range of $10^3 < \text{Re} < 10^5$, the drag coefficient remains relatively constant. This behavior is characteristic of blunt bodies. The flow in the boundary layer is laminar in this range, but the flow in the separated region past the cylinder or sphere is highly turbulent with a wide turbulent wake.
- There is a sudden drop in the drag coefficient somewhere in the range of $10^5 < \text{Re} < 10^6$ (usually, at about 2×10^5). This large reduction in C_D is due to the flow in the boundary layer becoming *turbulent,* which moves the separation point further on the rear of the body, reducing the size of the wake and thus the magnitude of the pressure drag. This is in contrast to streamlined bodies, which experience an increase in the drag coefficient (mostly due to friction drag) when the boundary layer becomes turbulent.

Fluid Mechanics Cengel & Cimbala





(a)



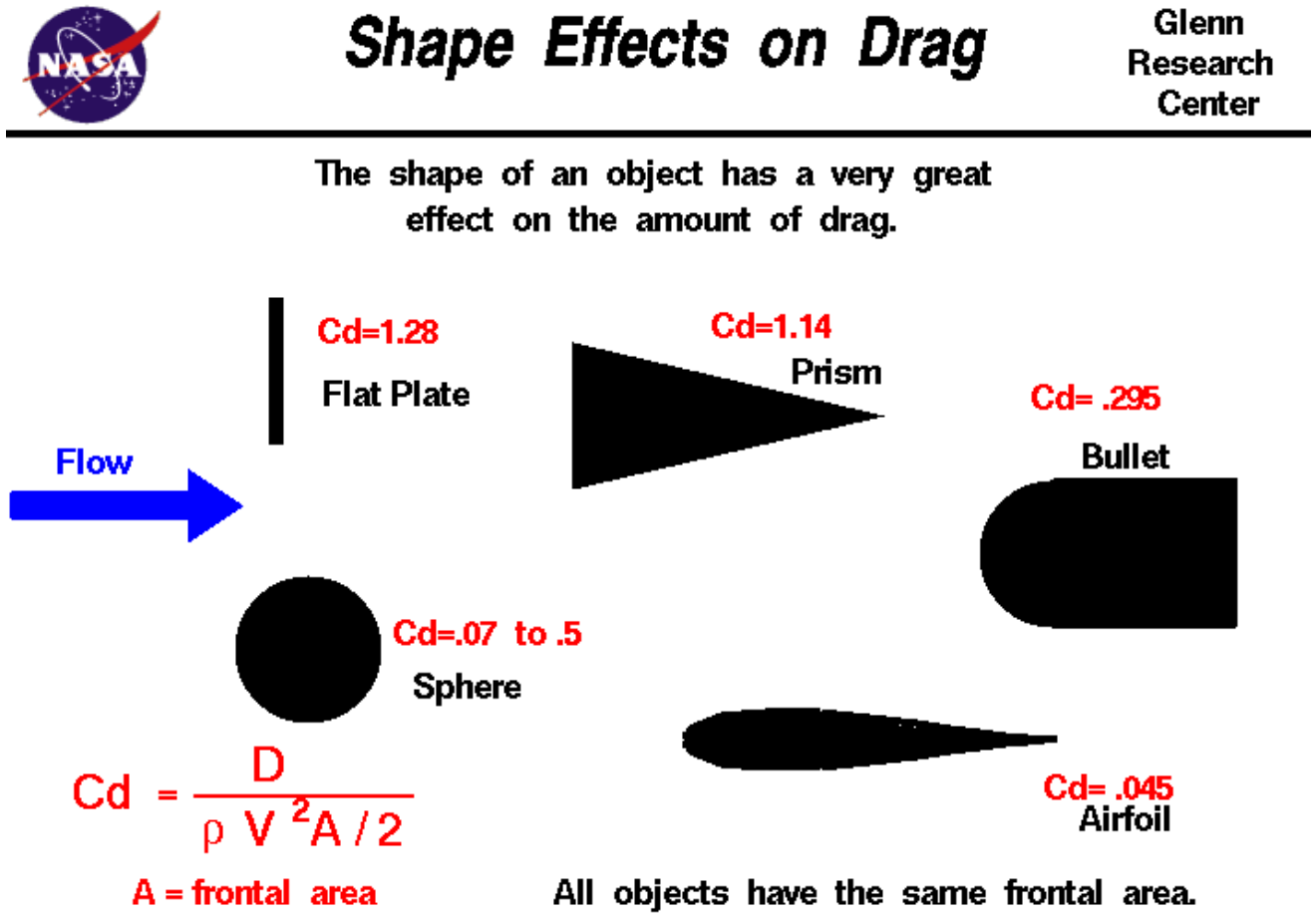
(b)

$$\text{Re} = \frac{v_{avg} D}{\nu} = \frac{100 * 0.0135}{1.48 * 10^{-5}}$$

$$= 91216.2$$

03.코일건모델링

COMSOL



$$F_D = \frac{1}{2}\rho v^2 C_D A$$

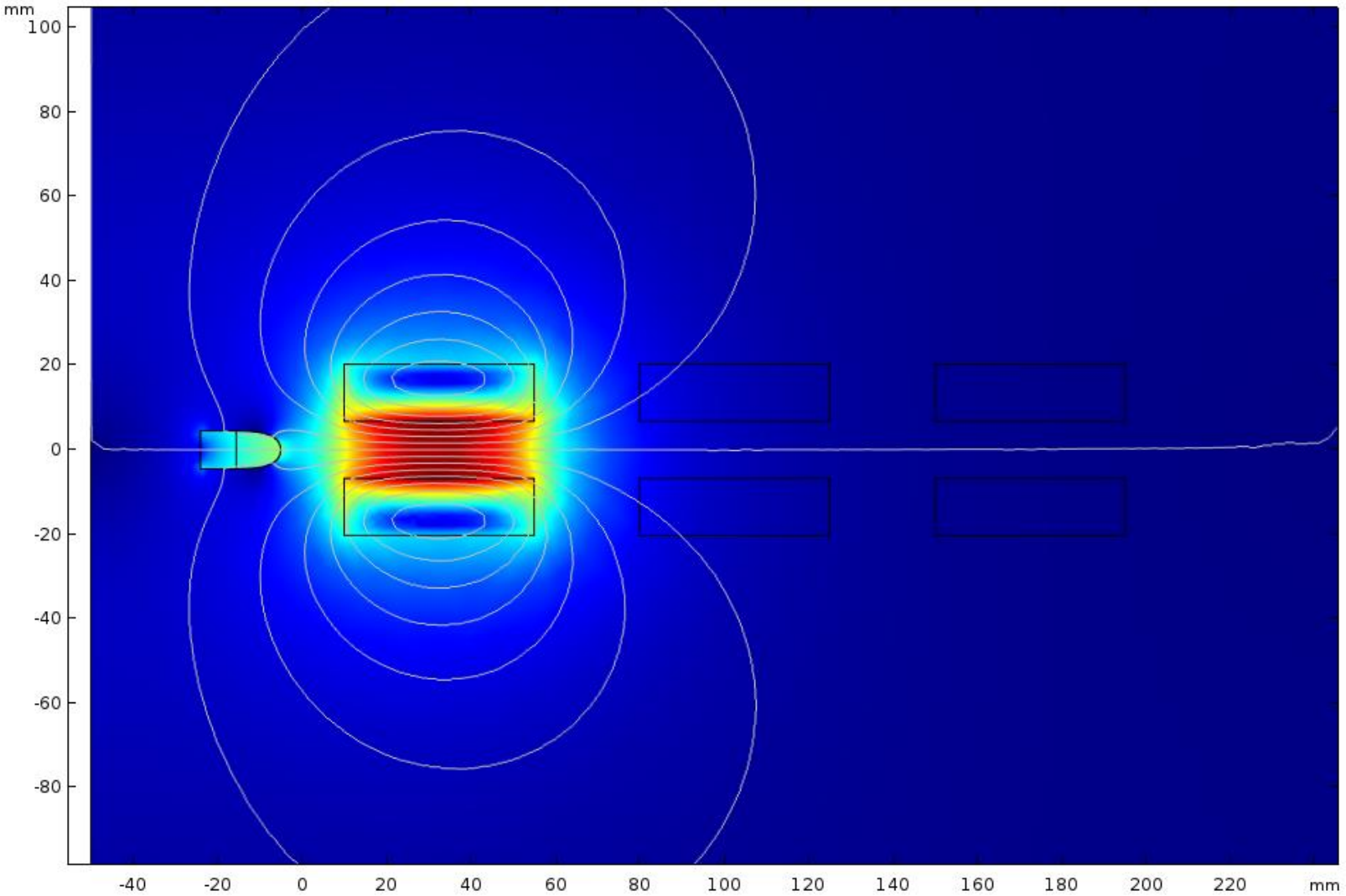
Anallytically	Numerically
$F_D = 0.111N$	$F_D = 0.160N$

04

코일건 분석

04. 코일건분석

COMSOL



- 자기장 *(mf)*
  - 암페어 법칙 1
  - 자기 절연 1
  - 초기 값 1
  - 암페어 법칙 2
  - 암페어 법칙 3
  - 외부 전류 밀도 1
  - 외부 전류 밀도 2
  - 힘 계산 1

전자기력 (#0), #1 성분, x 성분 (N)
829.40

04. 코일건분석

MATLAB

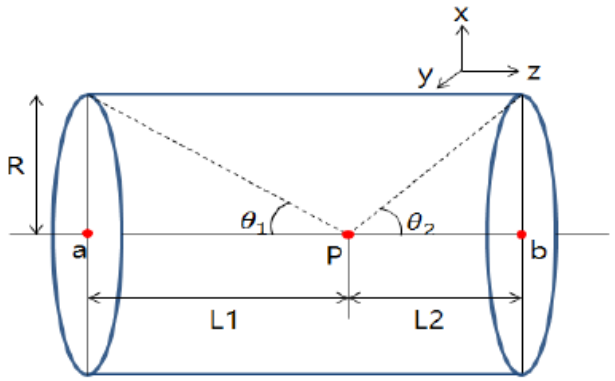


Fig. 2. Magnetic flux density at point P

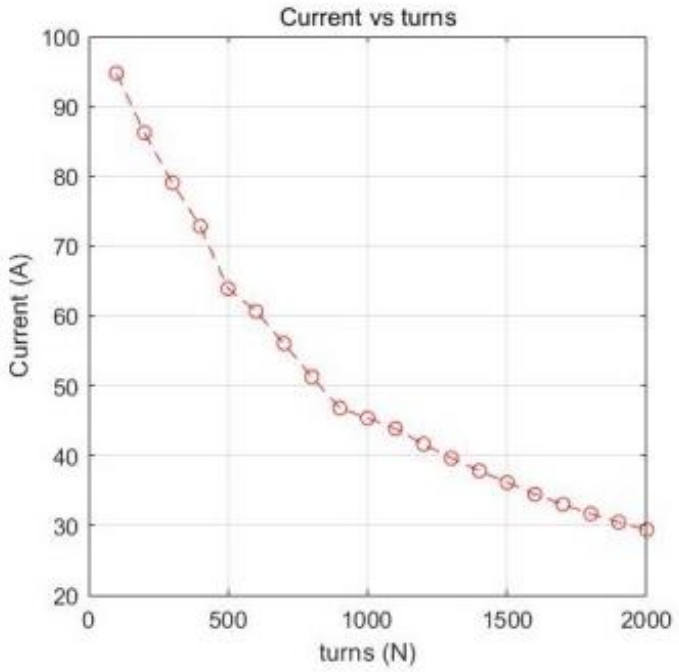
P에서의 자기장 B값은 식 (3)과 (4)를 통해 구할 수 있다.

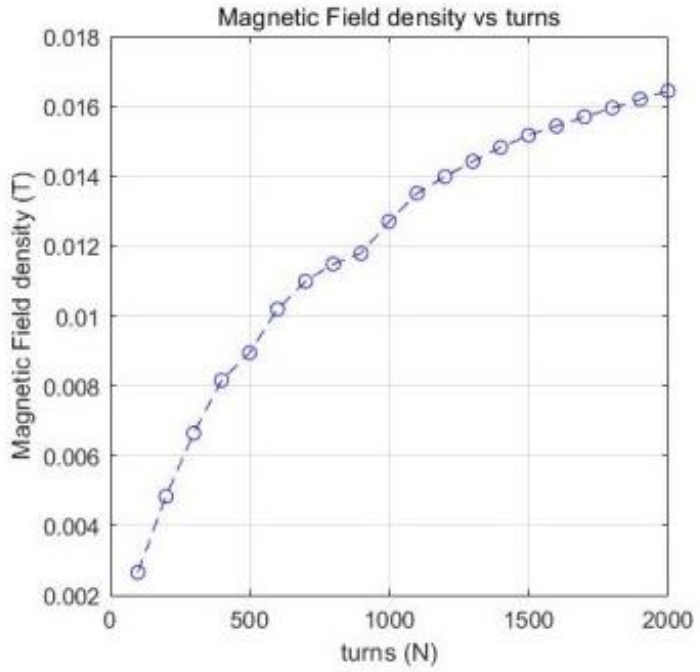
$$dB_z = \frac{\mu_0}{4\pi}\frac{nRi}{r^3}\,ds\,dz \tag{3}$$

$$B_z = \frac{\mu_0}{4\pi}nRi\int_0^{2\pi R} ds \int_{-a}^{b}\frac{dz}{r^3} \tag{4}$$

$$= \frac{\mu_0 ni}{2}\left[\frac{a}{\sqrt{R^2+a^2}}+\frac{b}{\sqrt{R^2+b^2}}\right]$$

$$= \frac{\mu_0 ni}{2}(\cos\theta_1+\cos\theta_2)$$

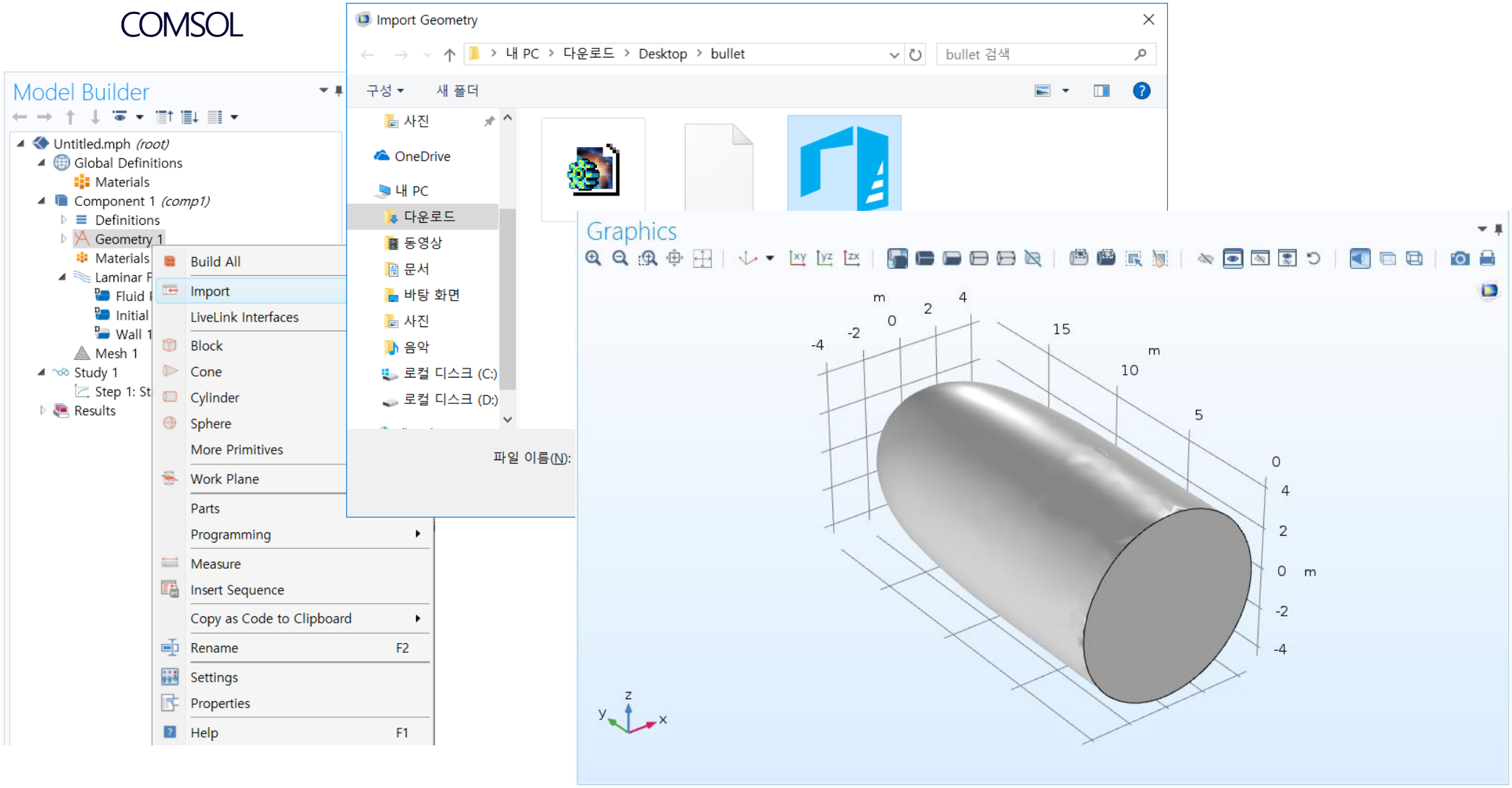




Turns와 Current, Magnetic field density 사이의 관계 예측

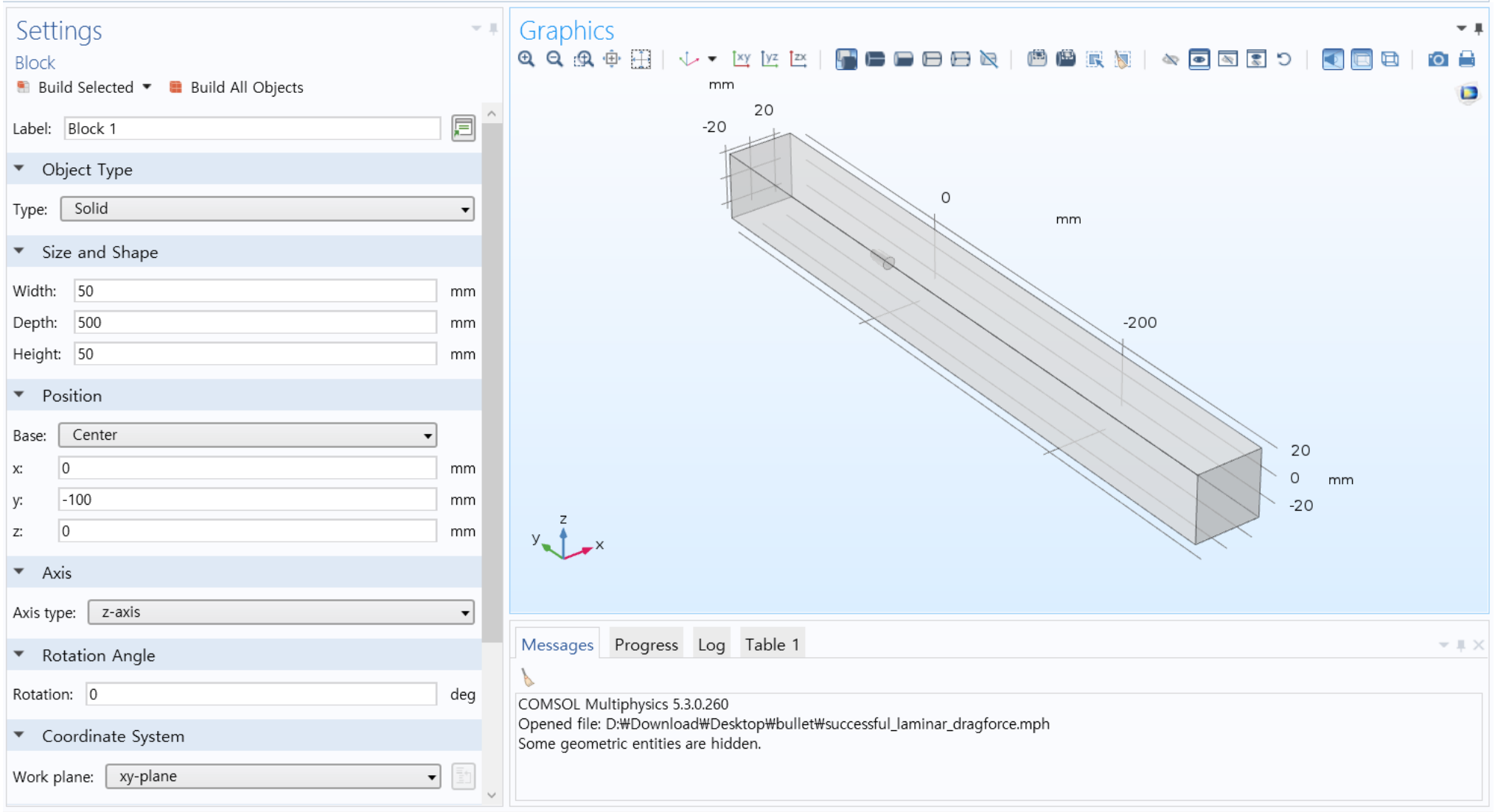
04. 코일건분석

COMSOL



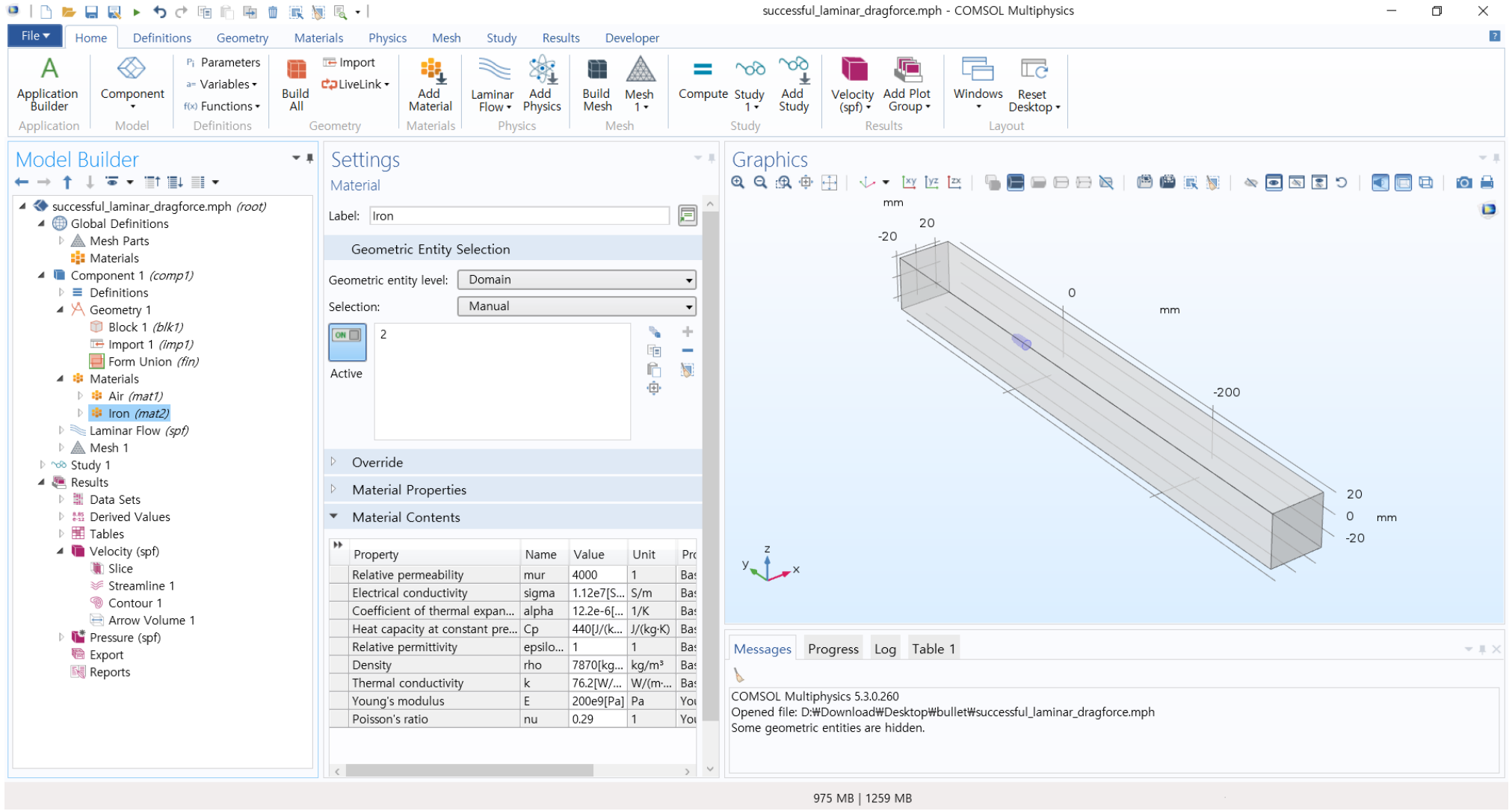
04. 코일건분석

COMSOL



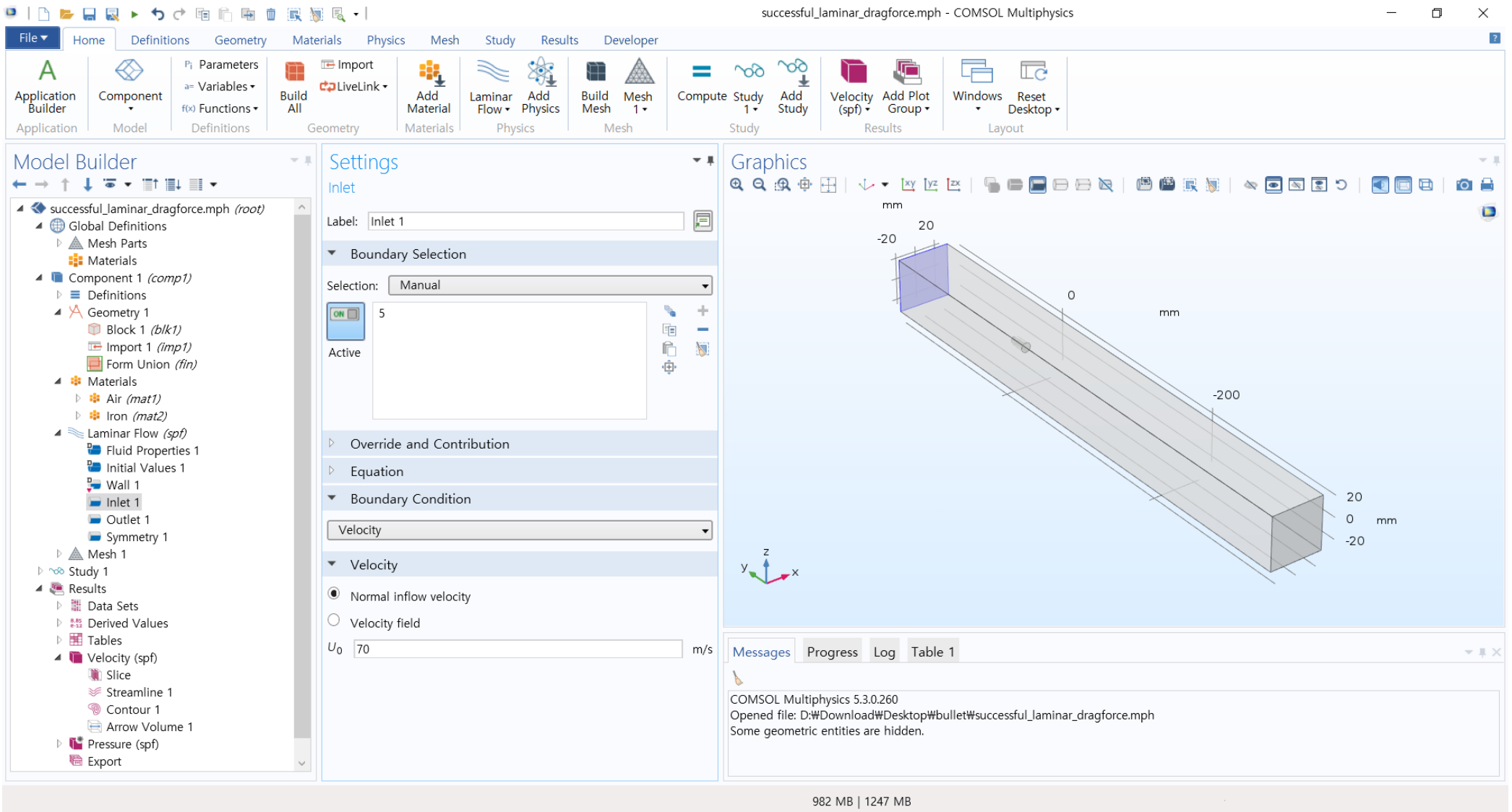
04. 코일건분석

COMSOL



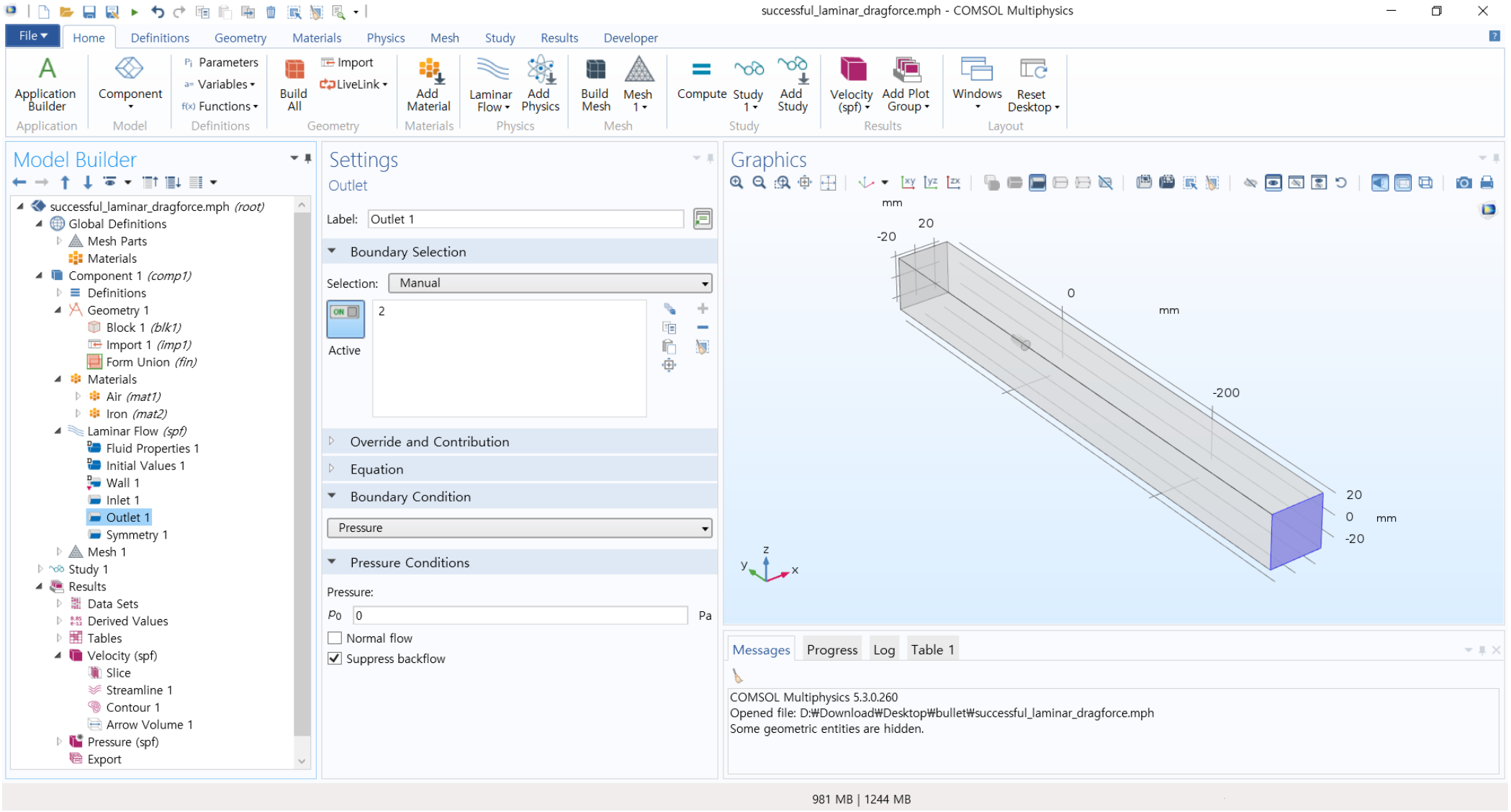
04. 코일건분석

COMSOL



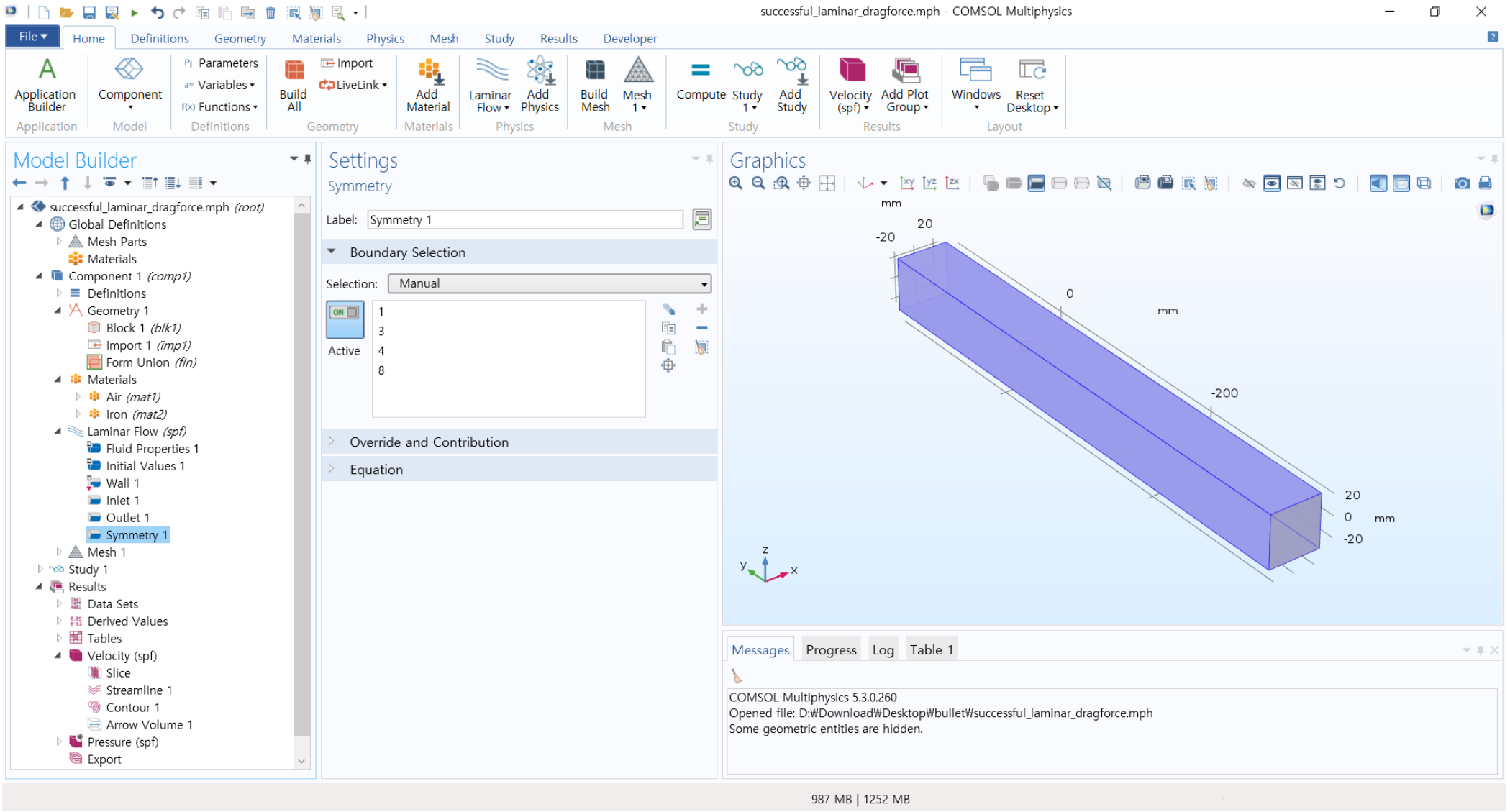
04. 코일건분석

COMSOL



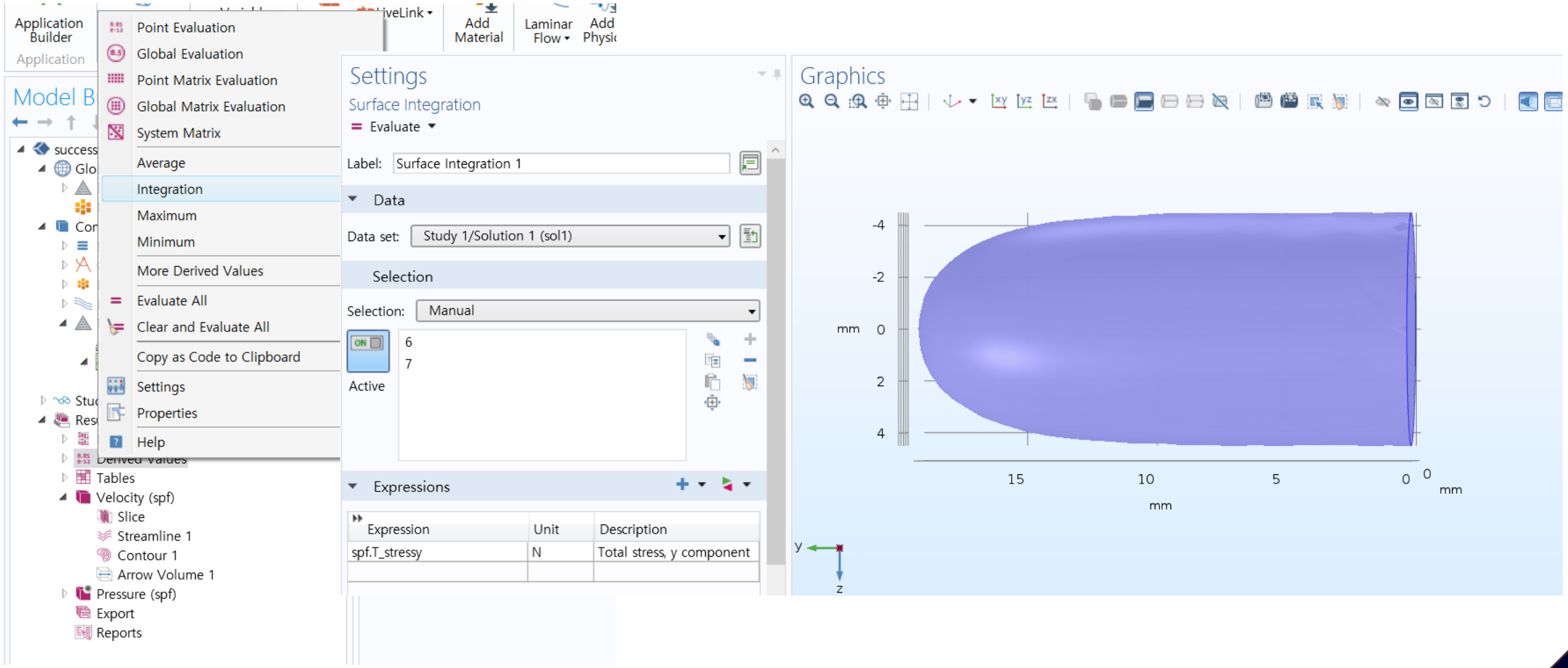
04. 코일건분석

COMSOL



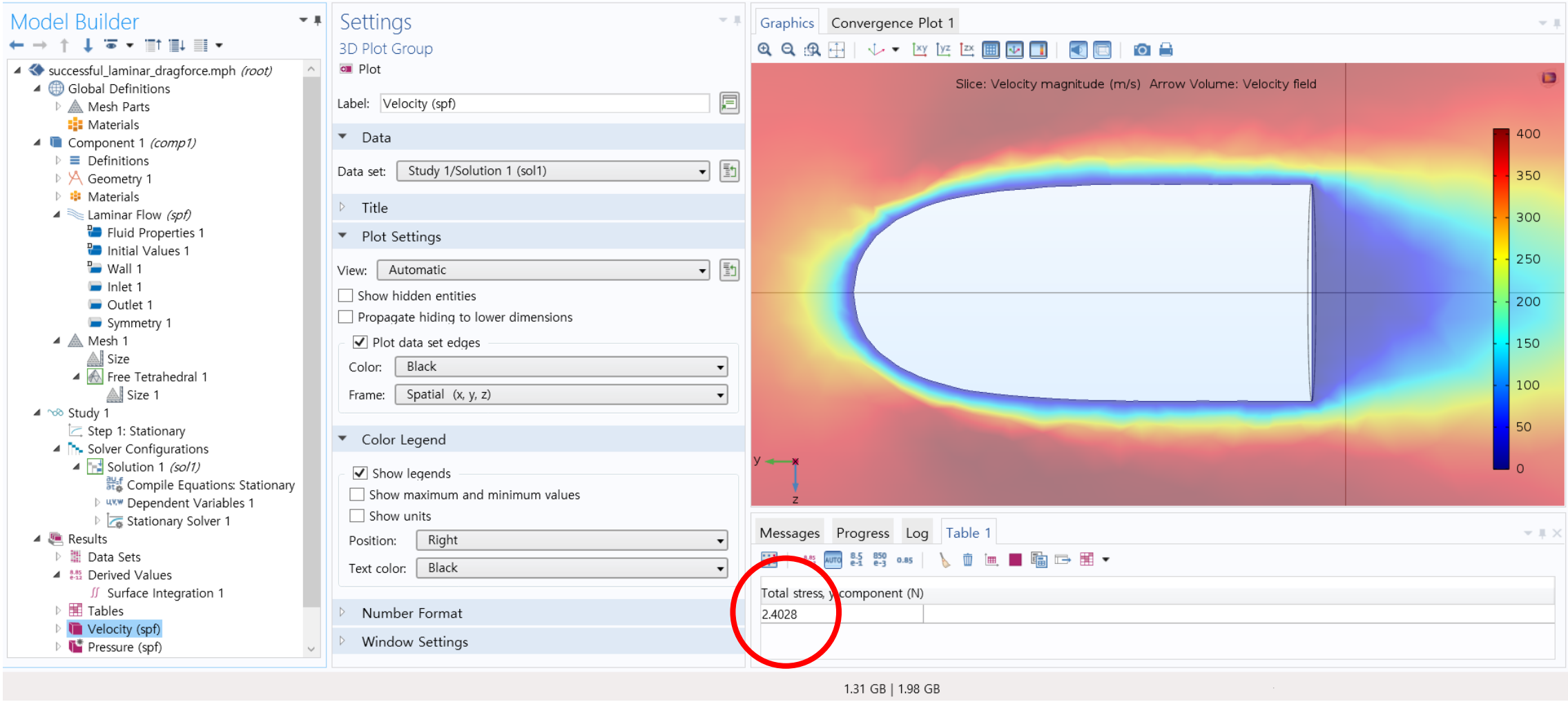
04. 코일건분석

COMSOL



04. 코일건분석

COMSOL

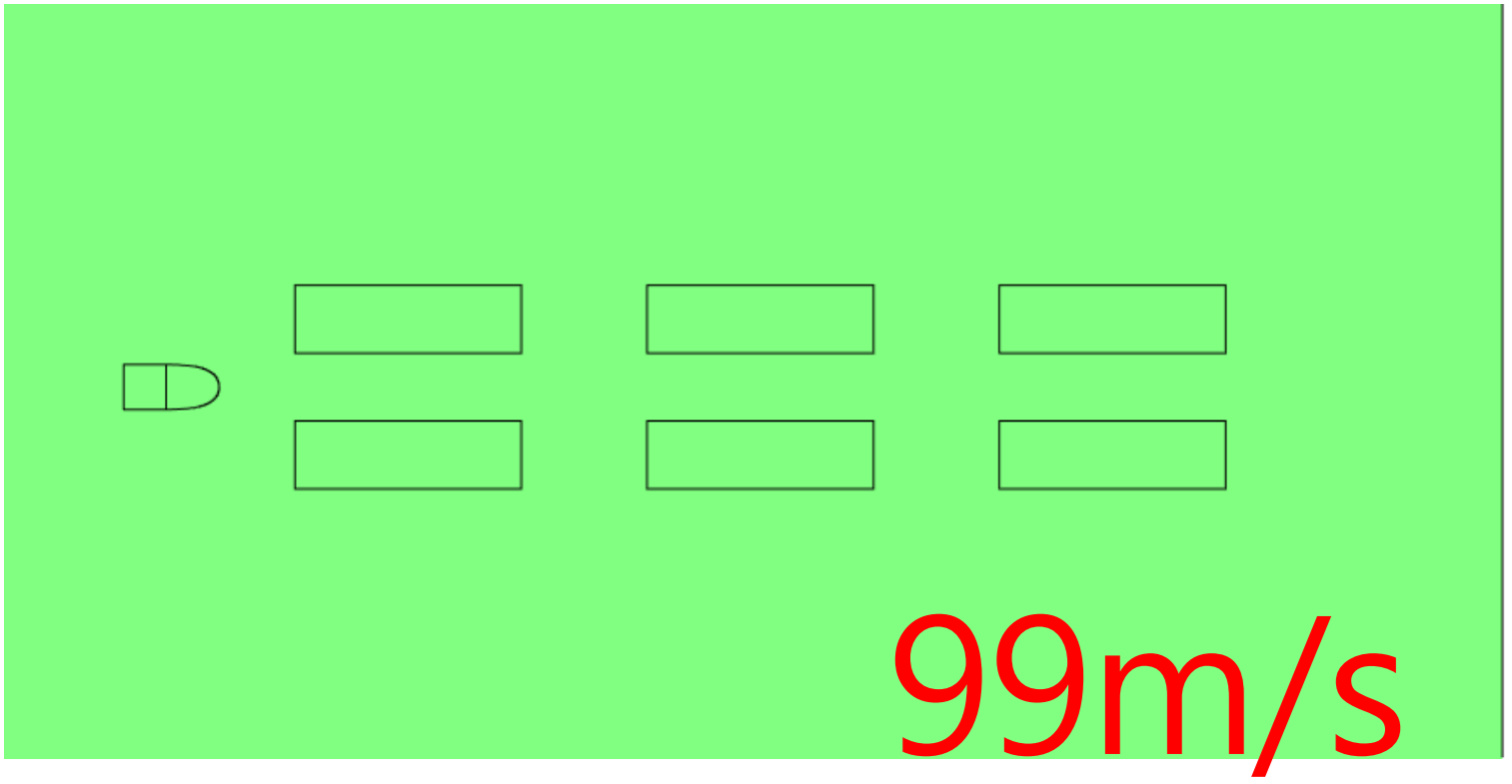


04. 코일건분석

EXCEL

1000turns

	A	B	C	D	E	F	G	H	I
1	time(s)	Current	Force(M)	Force(D)	Accel	Velocity	distance	distance(sum)	mass
2	0.5000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0103018
3	0.5001	0.63	0.05	0.00	4.94	0.00	0.00	0.00	
4	0.5002	1.27	0.21	0.00	19.92	0.00	0.00	0.00	
5	0.5003	1.90	0.46	0.00	44.58	0.01	0.00	0.00	
6	0.5004	2.53	0.82	0.00	79.52	0.01	0.00	0.00	
7	0.5005	3.16	1.27	0.00	123.14	0.03	0.00	0.00	
8	0.5006	3.79	1.83	0.00	177.64	0.04	0.00	0.01	
9	0.5007	4.42	2.49	0.00	241.55	0.07	0.01	0.01	
10	0.5008	5.05	3.24	0.00	314.23	0.10	0.01	0.02	
11	0.5009	5.68	4.12	0.00	399.56	0.14	0.01	0.03	
12	0.5010	6.30	5.08	0.00	492.70	0.19	0.02	0.05	
13	0.5011	6.93	6.15	0.00	596.62	0.25	0.02	0.07	
14	0.5012	7.55	7.34	0.00	712.03	0.32	0.03	0.10	
15	0.5013	8.18	8.60	0.00	834.56	0.40	0.04	0.14	
16	0.5014	8.80	9.99	0.00	969.90	0.50	0.05	0.18	
17	0.5015	9.42	11.59	0.00	1124.65	0.61	0.06	0.24	
18	0.5016	10.04	13.15	0.00	1276.37	0.74	0.07	0.31	
19	0.5017	10.56	14.76	0.00	1433.14	0.88	0.08	0.39	
20	0.5018	11.28	16.96	0.00	1646.31	1.05	0.10	0.48	
21	0.5019	11.89	19.18	0.00	1861.71	1.24	0.11	0.60	
22	0.5020	12.51	21.51	0.00	2087.88	1.44	0.13	0.73	
23	0.5021	13.13	24.06	0.00	2335.60	1.68	0.16	0.89	
24	0.5022	13.74	26.79	0.00	2600.70	1.94	0.18	1.07	
25	0.5023	14.35	29.96	0.00	2907.92	2.23	0.21	1.28	
26	0.5024	14.96	33.33	0.00	3235.53	2.55	0.24	1.52	
27	0.5025	15.57	37.43	0.00	3633.13	2.92	0.27	1.79	
28	0.5026	16.18	41.99	0.00	4075.86	3.32	0.31	2.10	
29	0.5027	16.79	46.98	0.00	4560.43	3.78	0.36	2.46	
30	0.5028	17.40	53.00	0.00	5144.21	4.29	0.40	2.86	
31	0.5029	18.00	59.73	0.00	5797.48	4.87	0.46	3.32	
32	0.5030	18.60	67.45	0.00	6547.43	5.53	0.52	3.84	
33	0.5031	19.21	76.84	0.00	7458.53	6.27	0.59	4.43	
34	0.5032	19.81	87.73	0.00	8516.28	7.13	0.67	5.10	
35	0.5033	20.41	102.86	0.00	9984.54	8.12	0.76	5.86	
36	0.5034	21.01	120.34	0.00	11681.30	9.29	0.87	6.73	
37	0.5035	21.61	144.01	0.00	13978.92	10.69	1.00	7.73	
38	0.5036	22.20	175.40	0.00	17025.90	12.39	1.15	8.88	
39	0.5037	22.80	218.15	0.00	21175.59	14.51	1.35	10.23	
40	0.5038	23.39	278.42	0.00	27025.91	17.21	1.59	11.82	
41	0.5039	23.98	368.25	0.01	35745.57	20.79	1.90	13.72	
42	0.5040	24.57	508.44	0.01	49353.61	25.72	2.33	16.04	
43	0.5041	25.16	733.41	0.01	71191.09	32.84	2.93	18.97	
44	0.5042	25.75	1085.00	0.02	105319.28	43.37	3.81	22.78	
45	0.5043	26.33	1560.30	0.03	151455.37	58.52	5.09	27.88	
46	0.5044	26.92	1971.90	0.06	191406.87	77.66	6.81	34.68	
47	0.5045	27.50	1650.20	0.10	160175.06	93.68	8.57	43.25	
48	0.5046	28.08	408.96	0.15	39683.17	97.65	9.57	52.82	
49	0.5047	0.63	0.01	0.16	-14.95	97.64	9.76	62.58	
50	0.5048	1.27	0.09	0.16	-6.85	97.64	9.76	72.35	
51	0.5049	1.90	0.67	0.16	48.96	97.65	9.76	82.11	
52	0.5050	2.53	4.40	0.16	410.96	97.69	9.77	91.88	
53	0.5051	3.16	21.49	0.16	2070.41	97.90	9.78	101.66	
54	0.5052	3.79	37.53	0.16	3626.96	98.26	9.81	111.46	
55	0.5053	4.42	19.74	0.17	1899.68	98.45	9.84	121.30	
56	0.5054	0.63	0.01	0.17	-15.36	98.45	9.84	131.14	
57	0.5055	1.27	0.08	0.17	-8.27	98.45	9.84	140.99	
58	0.5056	1.90	0.55	0.17	36.89	98.45	9.84	150.83	
59	0.5057	2.53	3.59	0.17	332.20	98.48	9.85	160.68	
60	0.5058	3.16	19.38	0.17	1865.14	98.67	9.86	170.54	
61	0.5059	3.79	37.71	0.17	3644.28	99.03	9.89	180.42	
62	0.5060	4.42	21.03	0.17	2024.66	99.24	9.91	190.34	

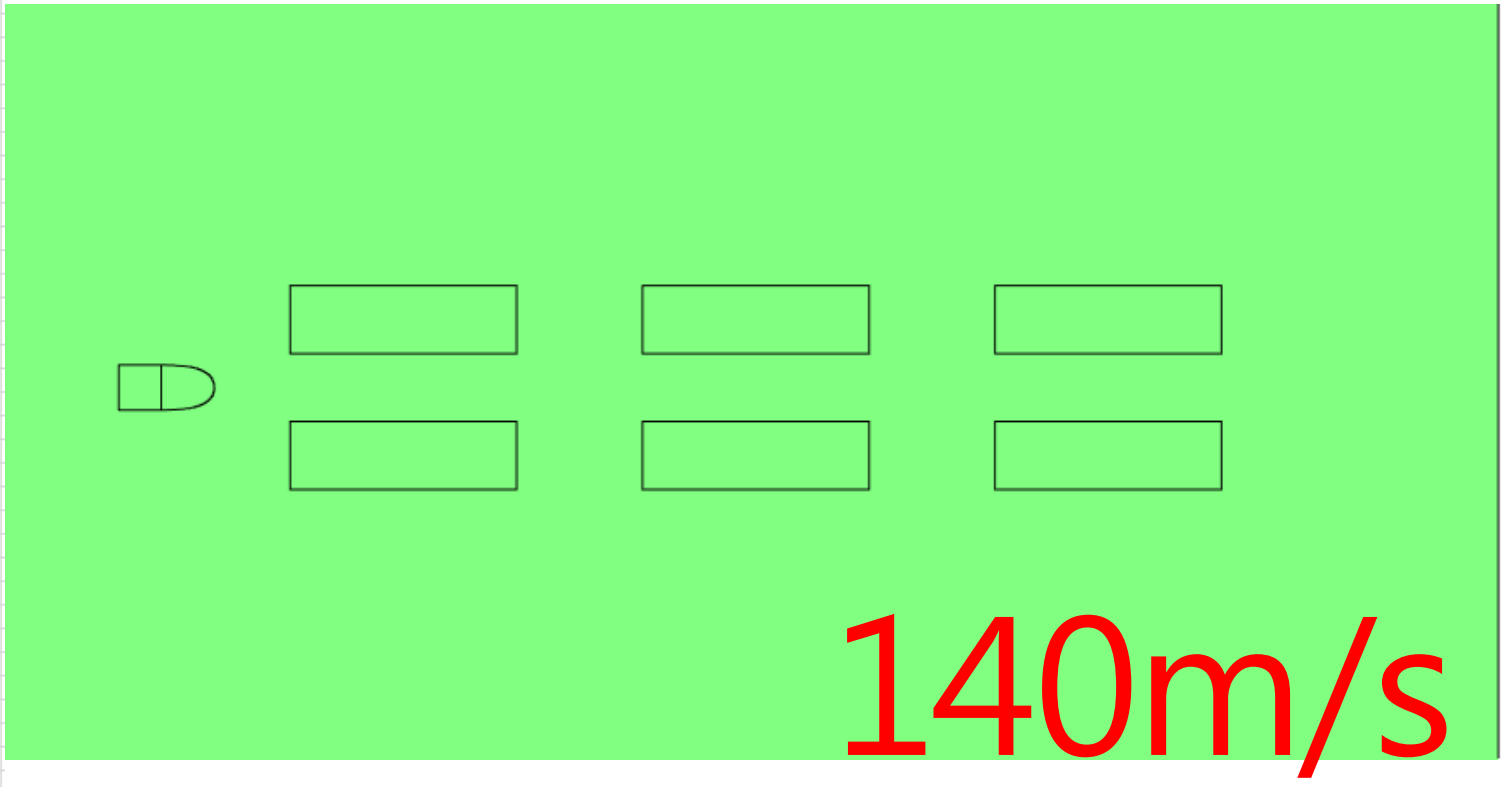


04. 코일건분석

EXCEL

500turns

	A	B	C	D	E	F	G	H	I
1	time(s)	Current	Force(M)	Force(D)	Acceleration	Velocity	distance	distance(sum)	mass
2	0.5000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01030183
3	0.5001	2.53	0.20	0.00	19.68	0.00	0.00	0.00	
4	0.5002	5.05	0.81	0.00	78.90	0.01	0.00	0.00	
5	0.5003	7.56	1.82	0.00	176.80	0.03	0.00	0.00	
6	0.5004	10.05	3.19	0.00	309.95	0.06	0.00	0.01	
7	0.5005	12.53	5.01	0.00	485.89	0.11	0.01	0.02	
8	0.5006	14.99	7.20	0.00	698.81	0.18	0.01	0.03	
9	0.5007	17.44	9.74	0.00	945.55	0.27	0.02	0.05	
10	0.5008	19.88	12.67	0.00	1229.88	0.39	0.03	0.09	
11	0.5009	22.30	15.94	0.00	1546.91	0.55	0.05	0.13	
12	0.5010	24.71	19.65	0.00	1907.14	0.74	0.06	0.20	
13	0.5011	27.10	23.87	0.00	2316.77	0.97	0.09	0.28	
14	0.5012	29.47	28.51	0.00	2767.76	1.25	0.11	0.39	
15	0.5013	31.84	33.85	0.00	3285.34	1.58	0.14	0.53	
16	0.5014	34.18	39.47	0.00	3831.26	1.96	0.18	0.71	
17	0.5015	36.51	46.39	0.00	4503.17	2.41	0.22	0.93	
18	0.5016	38.83	53.86	0.00	5227.89	2.93	0.27	1.20	
19	0.5017	41.13	62.70	0.00	6086.67	3.54	0.32	1.52	
20	0.5018	43.41	72.19	0.00	7007.37	4.24	0.39	1.91	
21	0.5019	45.68	84.90	0.00	8241.32	5.07	0.47	2.38	
22	0.5020	47.92	99.44	0.00	9652.90	6.03	0.55	2.93	
23	0.5021	50.16	116.08	0.00	11267.84	7.16	0.66	3.59	
24	0.5022	52.37	139.56	0.00	13547.02	8.51	0.78	4.37	
25	0.5023	54.57	167.30	0.00	16239.71	10.14	0.93	5.31	
26	0.5024	56.76	205.48	0.00	19945.79	12.13	1.11	6.42	
27	0.5025	58.92	255.75	0.00	24825.43	14.61	1.34	7.76	
28	0.5026	61.07	333.64	0.00	32386.11	17.85	1.62	9.38	
29	0.5027	63.20	451.10	0.01	43787.80	22.23	2.00	11.38	
30	0.5028	65.31	641.62	0.01	62281.30	28.46	2.53	13.92	
31	0.5029	67.40	983.24	0.01	95441.87	38.00	3.32	17.24	
32	0.5030	69.48	1628.60	0.02	158085.99	53.81	4.59	21.83	
33	0.5031	71.54	2694.70	0.05	261570.04	79.97	6.69	28.52	
34	0.5032	73.58	3669.80	0.11	356217.30	115.59	9.78	38.30	
35	0.5033	75.60	2283.50	0.23	221637.38	137.76	12.67	50.97	
36	0.5034	2.53	0.03	0.33	-28.37	137.75	13.78	64.74	
37	0.5035	5.05	0.48	0.33	14.54	137.75	13.78	78.52	
38	0.5036	7.56	5.91	0.33	541.89	137.81	13.78	92.30	
39	0.5037	10.05	55.80	0.33	5384.59	138.35	13.81	106.10	
40	0.5038	12.53	81.88	0.33	7916.51	139.14	13.87	119.98	
41	0.5039	2.53	0.03	0.33	-29.31	139.14	13.91	133.89	
42	0.5040	5.05	0.43	0.33	9.61	139.14	13.91	147.81	
43	0.5041	7.56	5.21	0.33	473.60	139.18	13.92	161.72	
44	0.5042	10.05	52.87	0.33	5099.83	139.69	13.94	175.67	
45	0.5043	12.53	81.39	0.33	7868.43	140.48	14.01	189.67	

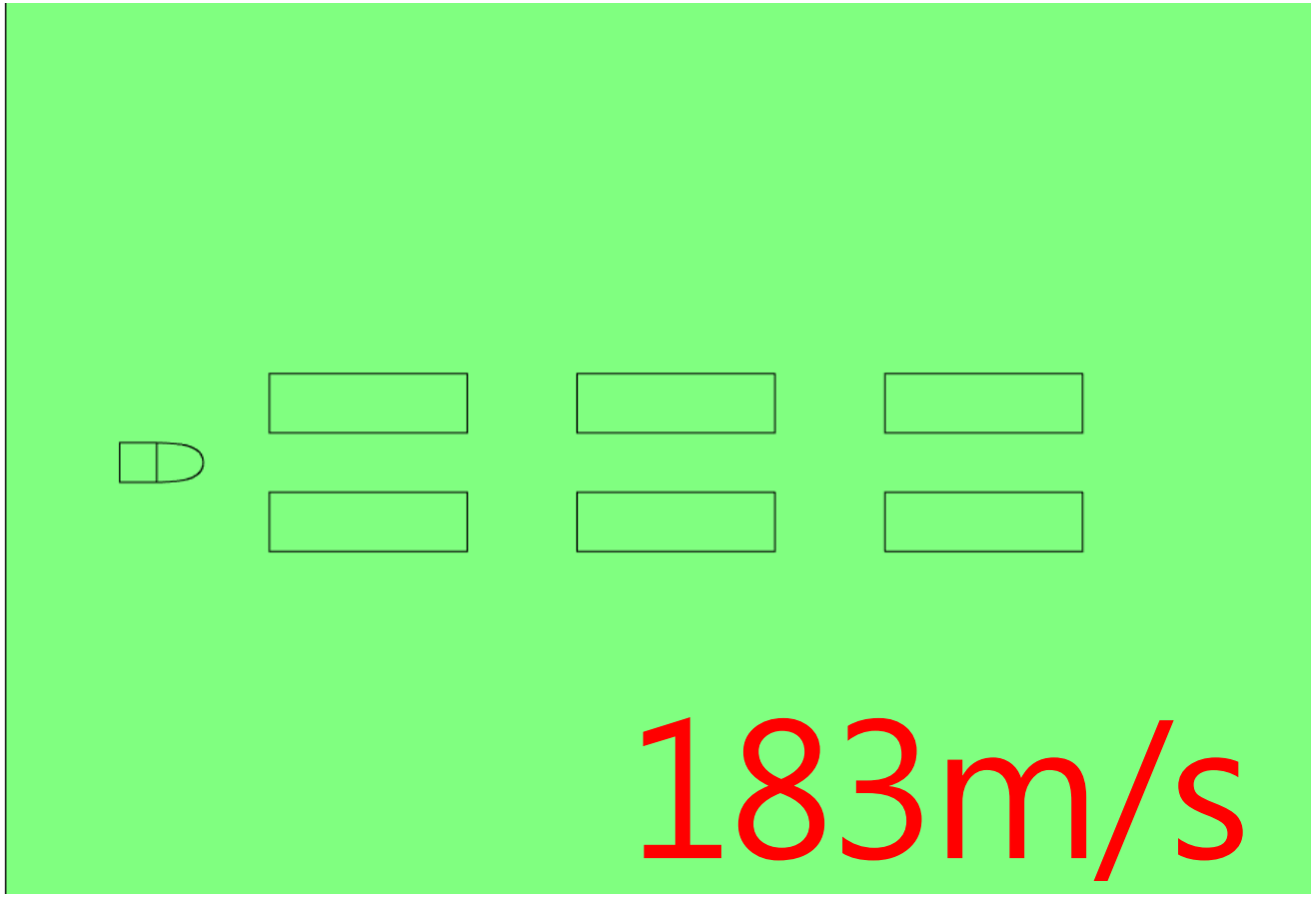


04. 코일건분석

EXCEL

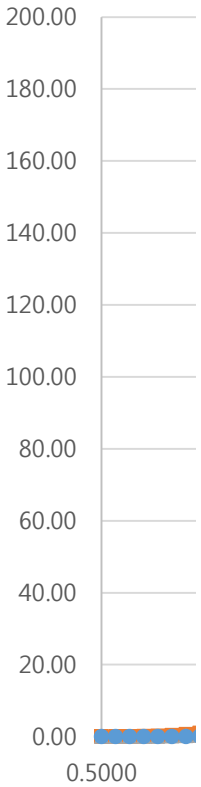
250turns

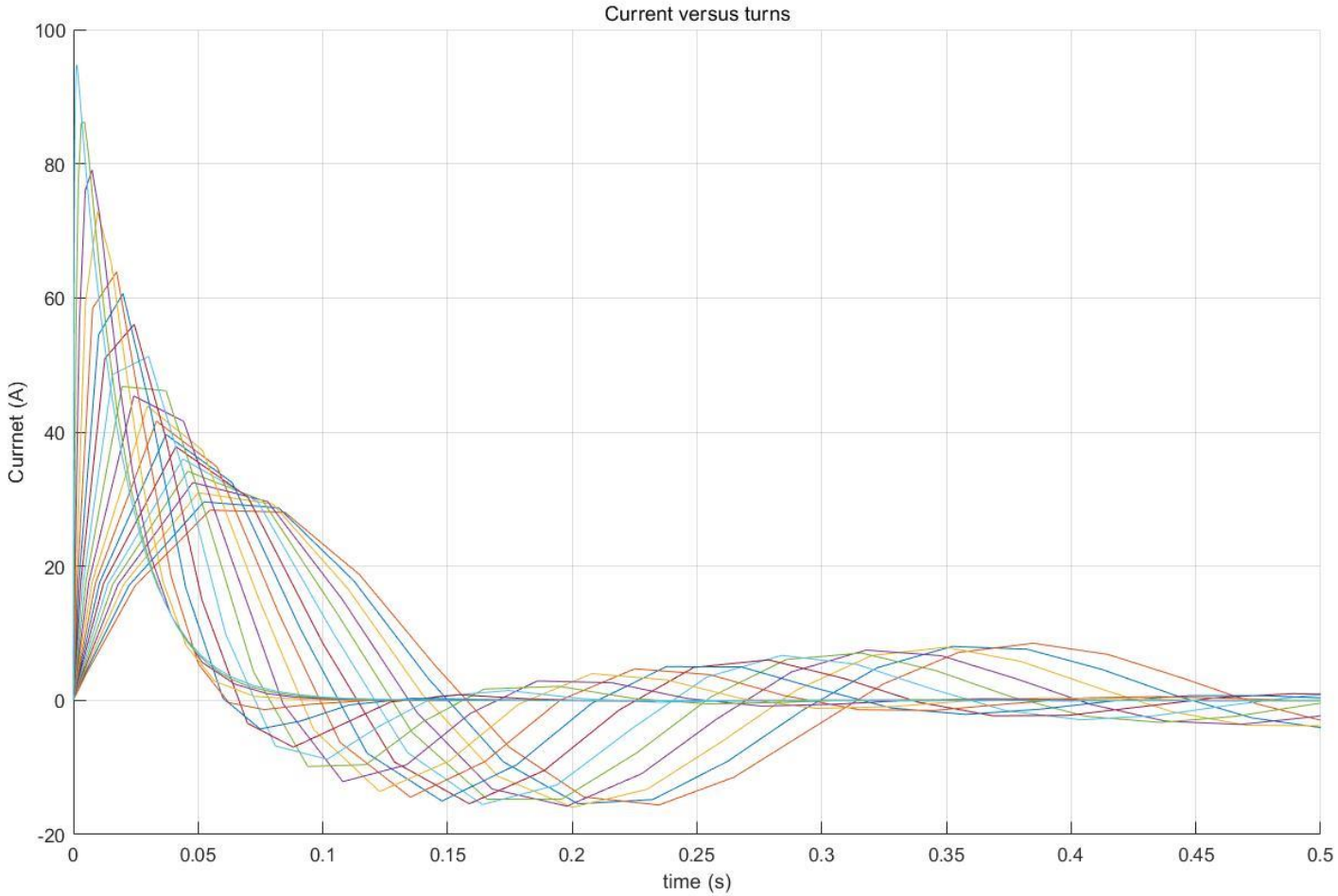
	A	B	C	D	E	F	G	H	I
1	time(s)	Current	Force(M)	Force(D)	Accelleration	Velocity	distance	distance(sum)	mass
2	0.5000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.010302
3	0.5001	10.03	0.80	0.00	77.25	0.01	0.00	0.00	
4	0.5002	19.87	3.14	0.00	304.46	0.04	0.00	0.00	
5	0.5003	29.51	6.93	0.00	672.82	0.11	0.01	0.01	
6	0.5004	38.94	12.10	0.00	1174.55	0.22	0.02	0.03	
7	0.5005	48.17	18.53	0.00	1798.52	0.40	0.03	0.06	
8	0.5006	57.19	26.17	0.00	2540.42	0.66	0.05	0.11	
9	0.5007	66.00	35.03	0.00	3400.46	1.00	0.08	0.19	
10	0.5008	74.61	45.45	0.00	4412.22	1.44	0.12	0.31	
11	0.5009	83.01	56.70	0.00	5503.58	1.99	0.17	0.49	
12	0.5010	91.20	70.33	0.00	6827.03	2.67	0.23	0.72	
13	0.5011	99.19	85.81	0.00	8329.48	3.50	0.31	1.03	
14	0.5012	107.00	103.86	0.00	10081.68	4.51	0.40	1.43	
15	0.5013	114.60	125.16	0.00	12149.26	5.73	0.51	1.94	
16	0.5014	121.90	150.94	0.00	14651.71	7.19	0.65	2.59	
17	0.5015	129.10	186.07	0.00	18061.75	9.00	0.81	3.40	
18	0.5016	136.10	229.55	0.00	22282.31	11.23	1.01	4.41	
19	0.5017	142.90	287.60	0.00	27917.15	14.02	1.26	5.67	
20	0.5018	149.50	374.72	0.00	36373.78	17.66	1.58	7.25	
21	0.5019	155.80	503.92	0.01	48915.05	22.55	2.01	9.26	
22	0.5020	162.00	726.43	0.01	70513.79	29.60	2.61	11.87	
23	0.5021	168.00	1132.50	0.02	109930.45	40.59	3.51	15.38	
24	0.5022	173.80	2001.60	0.03	194292.81	60.02	5.03	20.41	
25	0.5023	179.40	3761.60	0.06	365132.99	96.53	7.83	28.24	
26	0.5024	184.80	5827.40	0.16	565650.95	153.10	12.48	40.72	
27	0.5025	190.10	2754.40	0.40	267330.95	179.83	16.65	57.37	
28	0.5026	10.03	0.22	0.55	-32.63	179.83	17.98	75.35	
29	0.5027	19.87	6.45	0.55	571.90	179.89	17.99	93.34	
30	0.5028	29.51	128.81	0.55	12449.75	181.13	18.05	111.39	
31	0.5029	38.94	97.22	0.56	9382.36	182.07	18.16	129.55	
32	0.5030	10.03	0.27	0.57	-29.28	182.07	18.21	147.75	
33	0.5031	19.87	8.96	0.57	814.43	182.15	18.21	165.96	
34	0.5032	29.51	142.11	0.57	13739.42	183.52	18.28	184.25	
35	0.5033	38.94	49.73	0.58	4770.95	184.00	18.38	202.62	
36	0.5034	0.00	0.00	0.58	-56.35	183.99	18.40	221.02	
37	0.5035	0.00	0.00	0.58	-56.34	183.99	18.40	239.42	
38	0.5036	0.00	0.00	0.58	-56.34	183.98	18.40	257.82	



04. 코일건분석

EXCEL

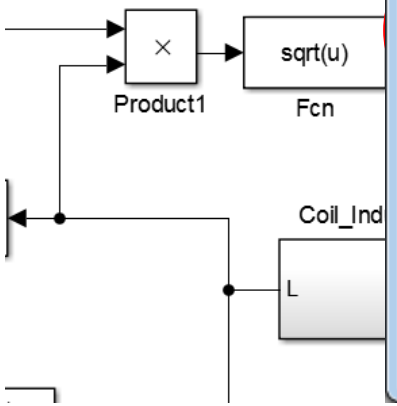


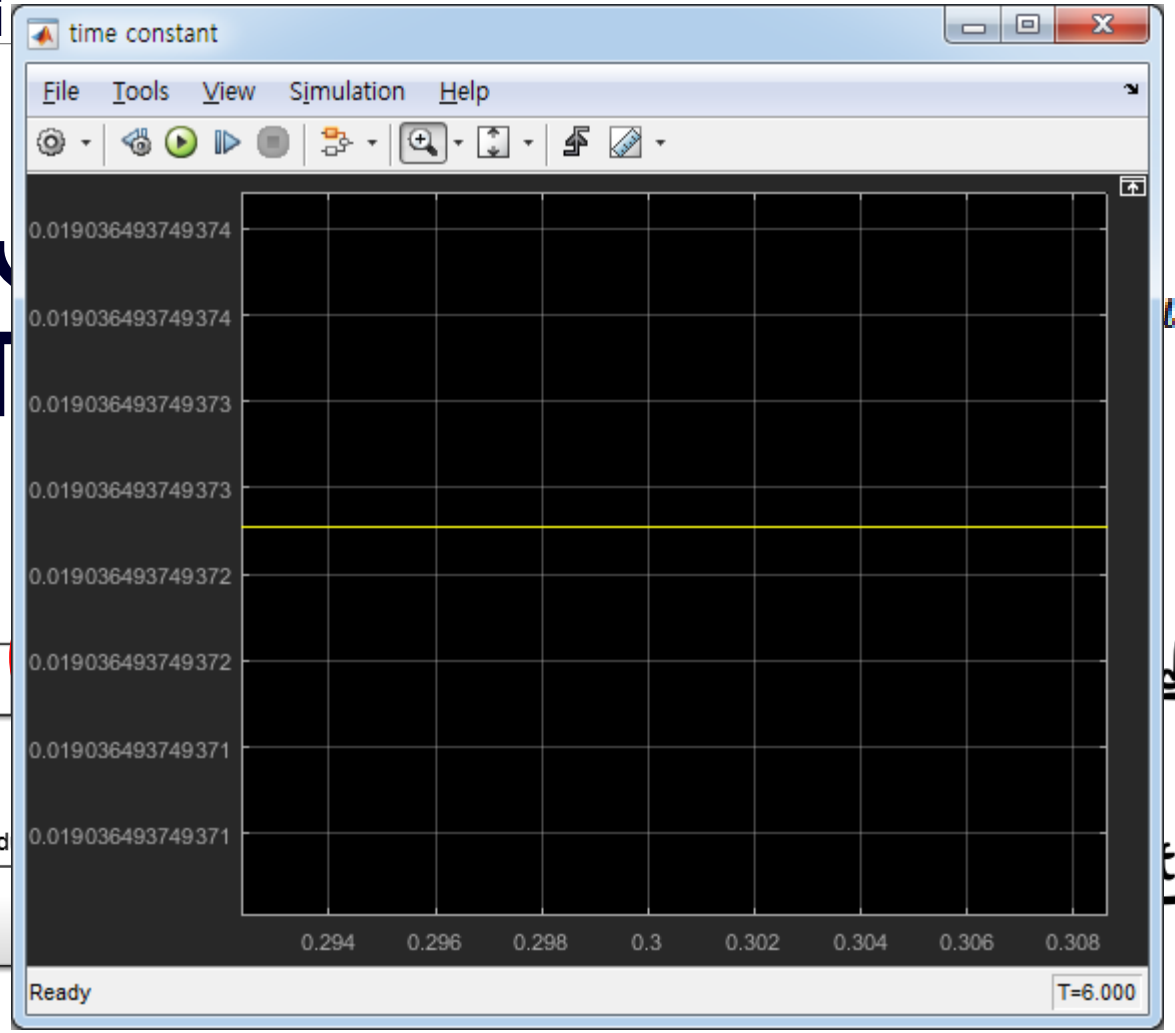


04. 코일건분석

EXCEL

시상수





$$\iota(t-\theta_p)$$

$$\frac{di_2(t)}{dt} = 0$$

$$+ L\frac{d^2q_2(t)}{dt} = 0$$

$$\tau = \sqrt{LC}$$

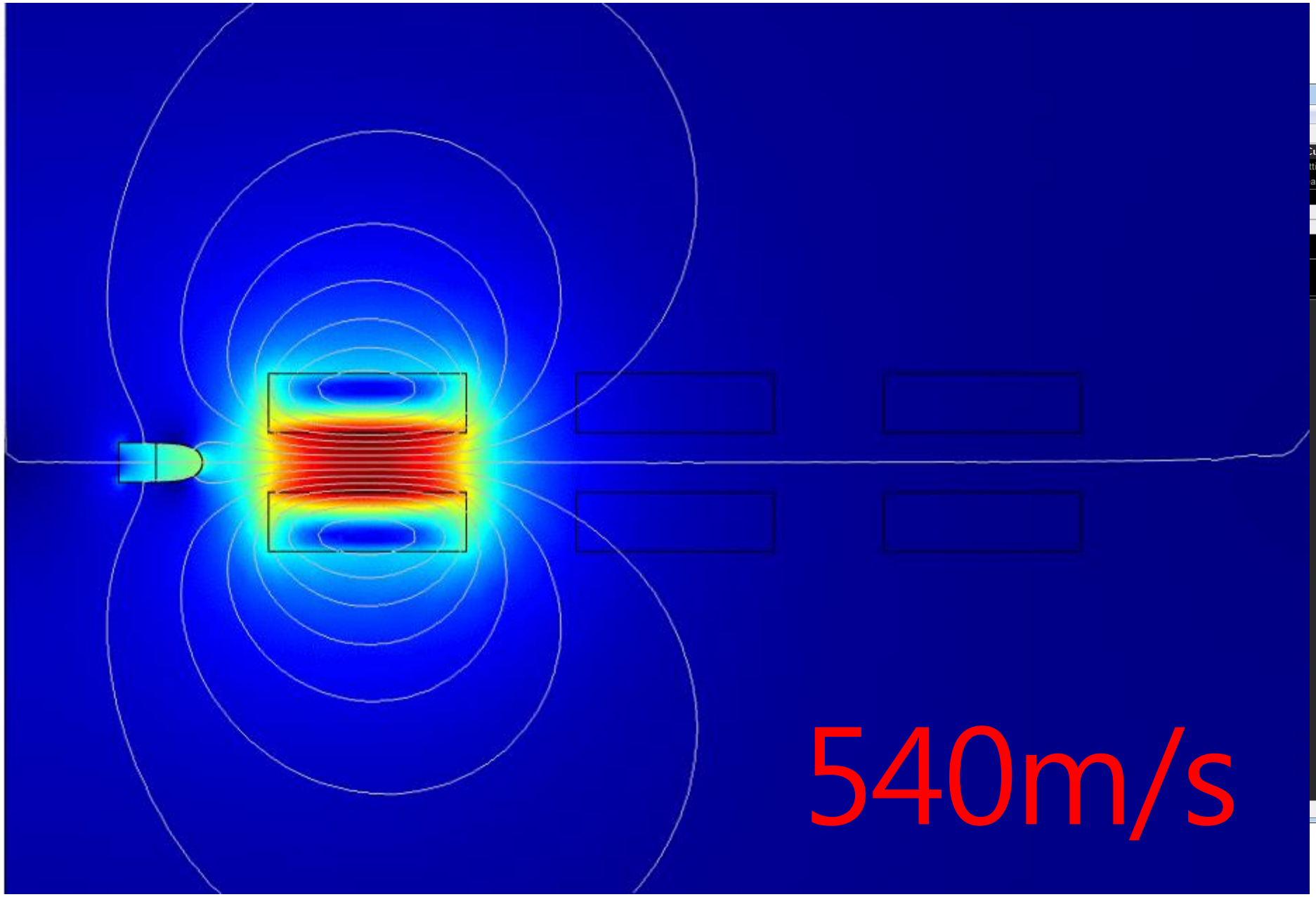
04. 코

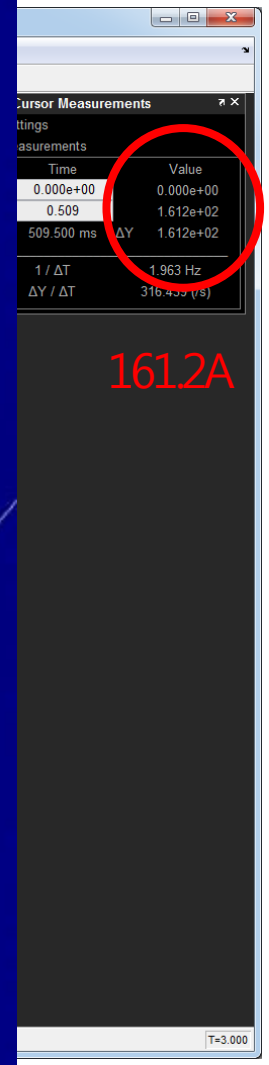
EXCEL

500turns

	A	
1	time(s)	Curre
2	0.5094	
3	0.5095	1
4	0.5096	1
5	0.5097	1
6	0.5098	1
7	0.5099	1
8	0.5100	1
9	0.5101	1
10	0.5102	1
11	0.5103	1
12	0.5104	1
13	0.5105	1

기존의 0s





04. 코일건분석

토의

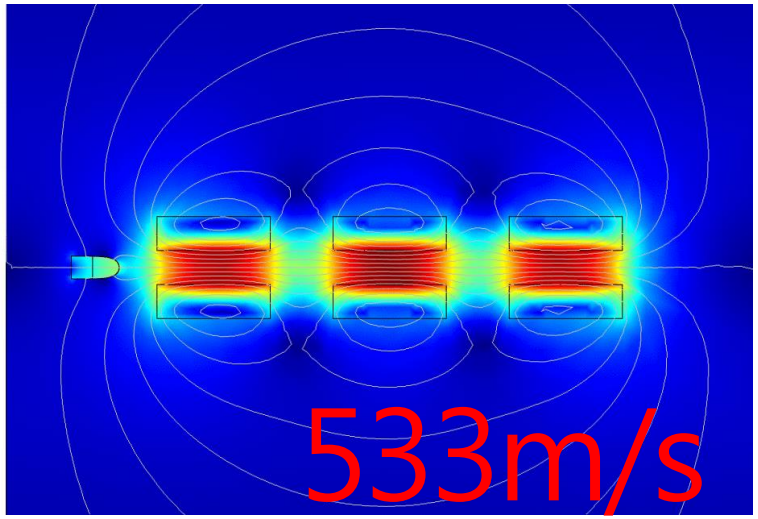
3개의 코일에 가하는 전류를 시상수 일 때부터 인가하려면?

→ 3개의 코일에 전류를 동시에 흘리자!

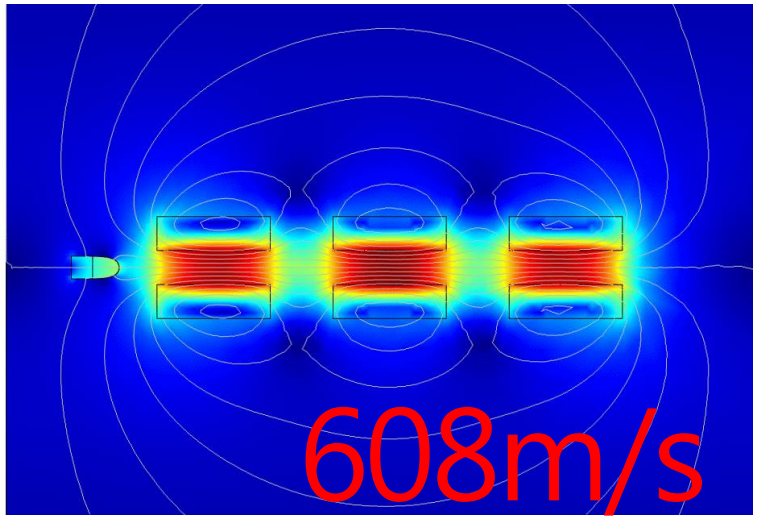
04. 코일건분석

EXCEL+COMSOL

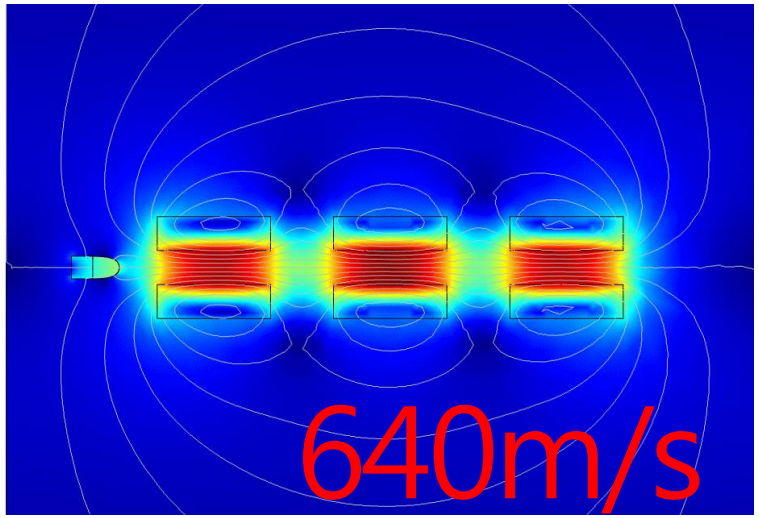
250turns



500turns



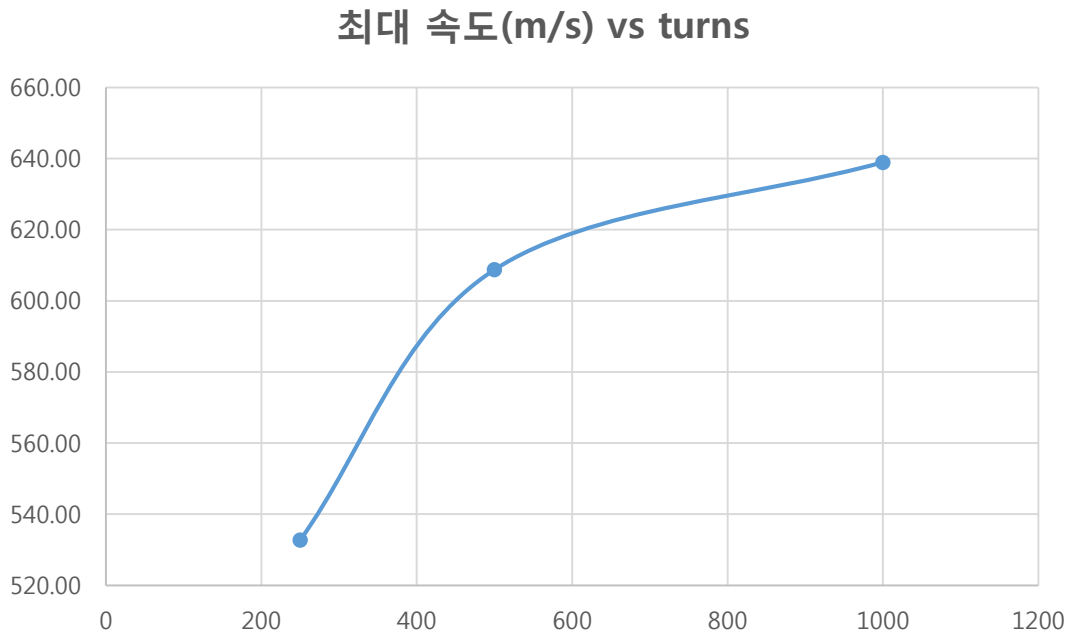
1000turns

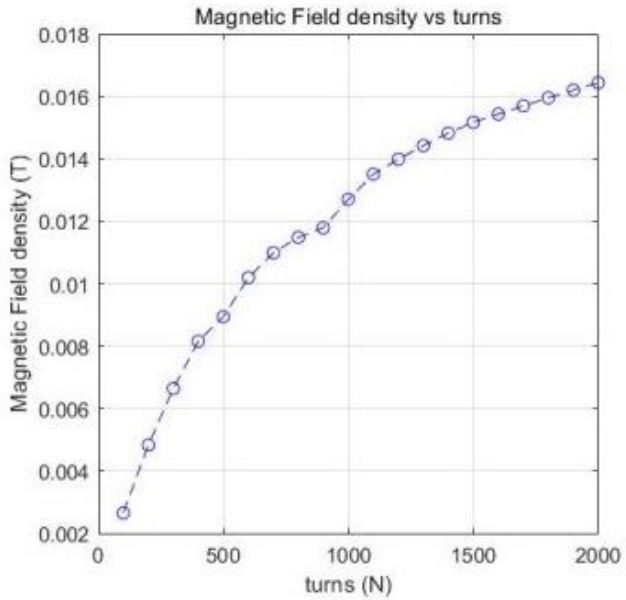


시상수 고려 후 총알속도

04. 코일건분석

결론





예측했던 결과와 같은 경향을 보인다.

04. 코일건분석

결론

탄자 중량	115 그레인(7.5 그램)~85 그레인(5.5 그램)[1]
총구초속	340~450 m/s
운동에너지	약 450~650 J[2]

실제 권총의 속도와 에너지

탄자 중량	**10.3 그램**
총구 속도	533~640 m/s (시상수)
운동 에너지	약 1463~2110 J

코일건의 속도와 에너지 (실험값)

04. 코일건분석

결론+제언

1. turns 마다 전류의 시상수가 다르므로 제어에 고려해야 한다.

2. 같은 길이 내에 더 많은 코일을 감을 수록 속도는 빨라진다.

3. 코일의 개수를 늘려도 속도는 무한히 증가하지 않는다.

4. 정밀한 제어를 할 수 있다면 엄청난 파괴력을 얻을 수 있다.

5. 미래의 상용화 가능성

Thank you

가우스 X의 헌신