Simulation and comparison of Parcel Robot

Automotive Engineering

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Background

-Related situation

-Idea source

Simulation(numerical result)

1. Drag force (comsol)
2. SOC (simulink)
3. Gear (comsol)

Comparison of Numerical and Actual result

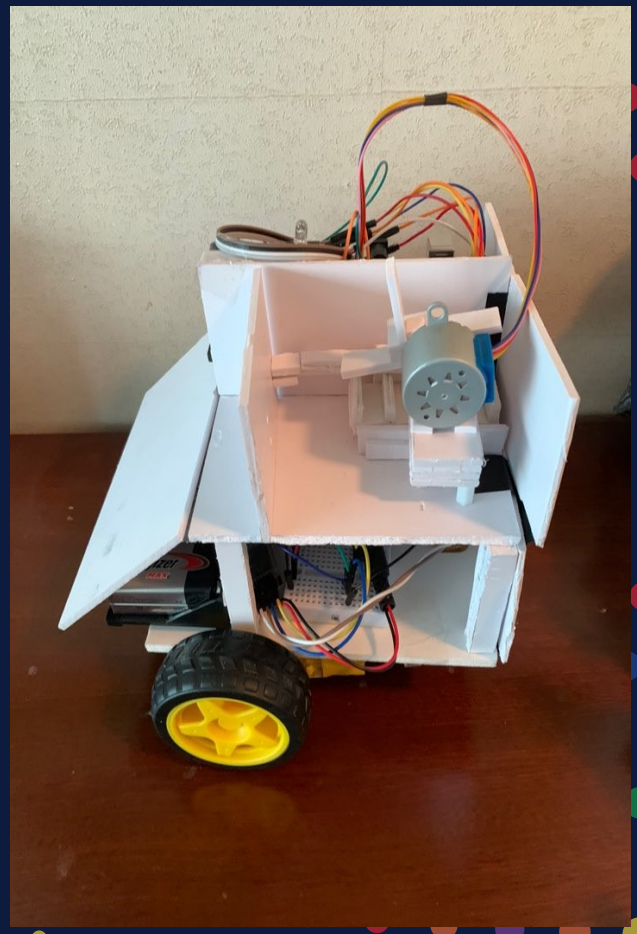
1. Background

Why did we choose this?

1. Background

- Robot that delivers parcels from one floor to another

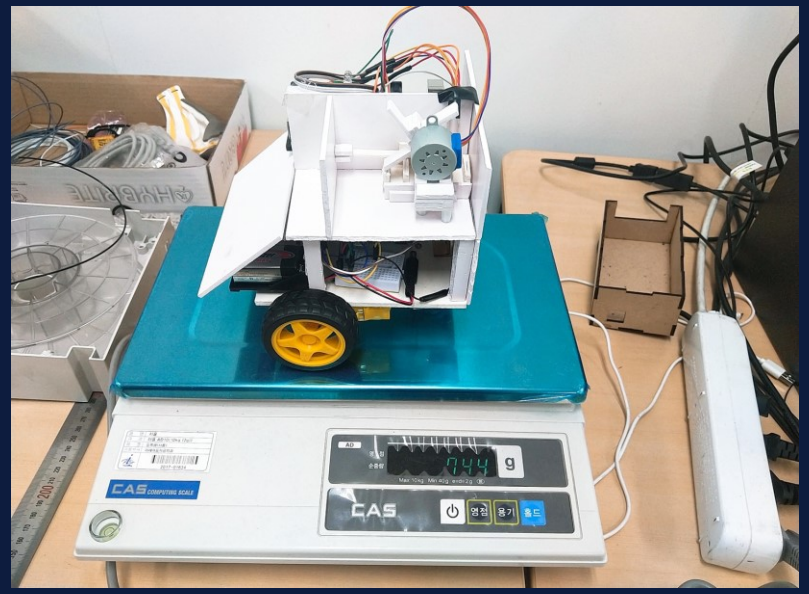
- **Know Yourself!!**
- Compare **Numerical and Actual** results



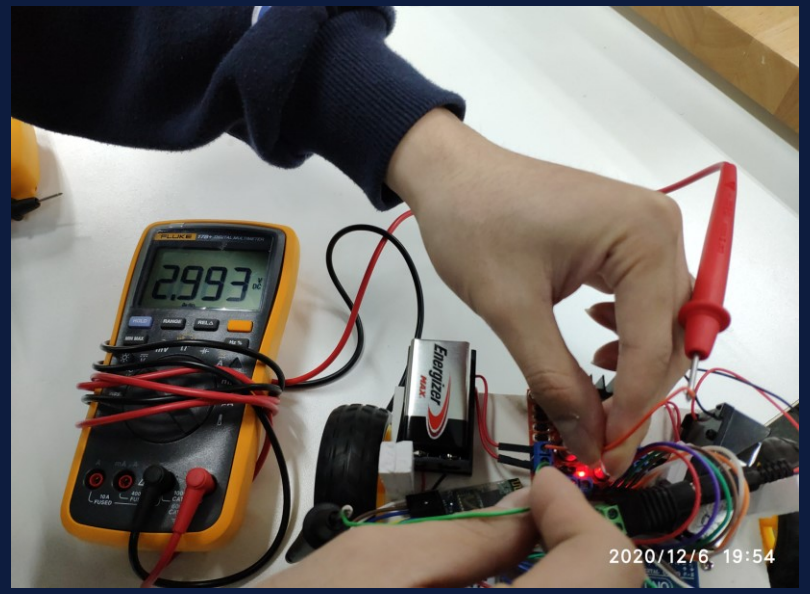
2. Simulation

To Obtain Numerical Result

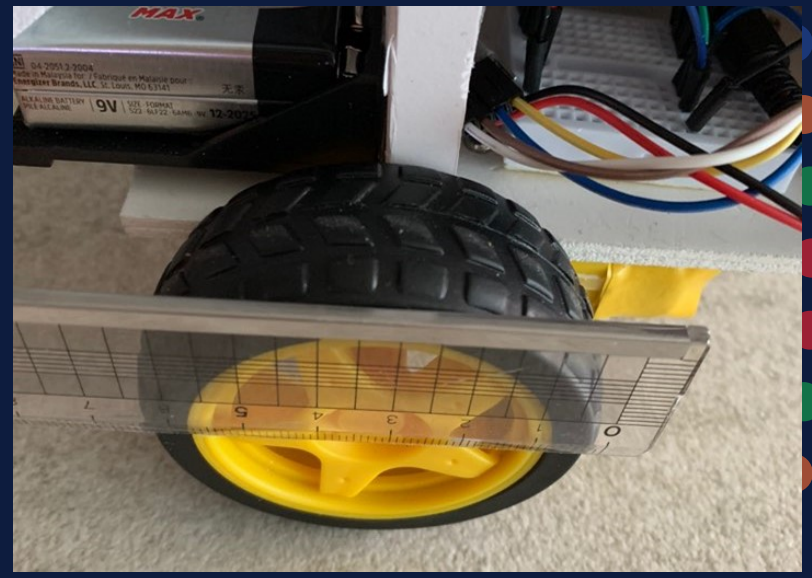
2. Specifications



Vehicle mass

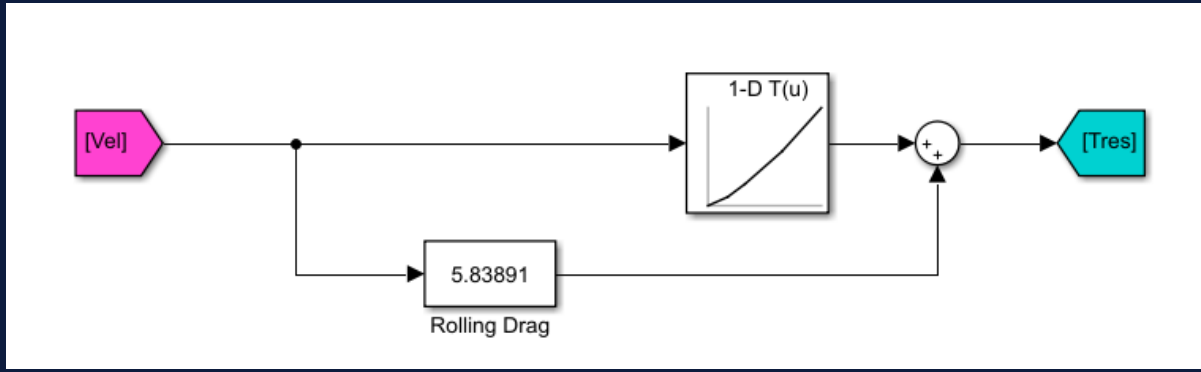


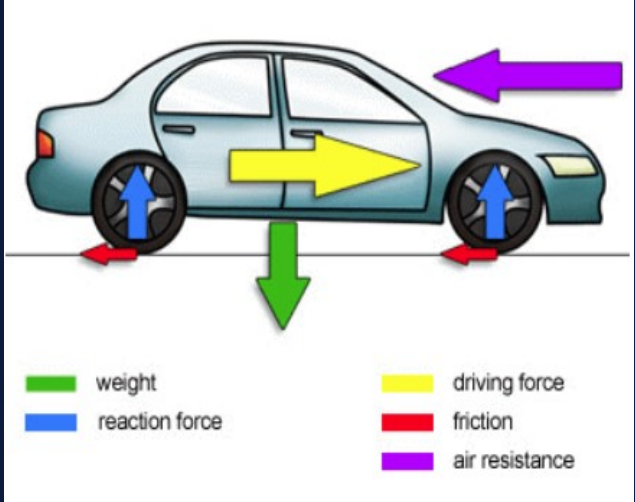
V_bat



R_tire

2-1. COMSOL-Resistance Model





1. Air resistance

$$F_{air} = \frac{1}{2} C_d A_{fr} \rho_{air} V_{veh}^2$$

C_d : air drag coefficient

A_{fr} : frontal area [m^2]

ρ_{air} : air density [kg/m^3]

V_{veh} : vehicle speed [m/s^2]

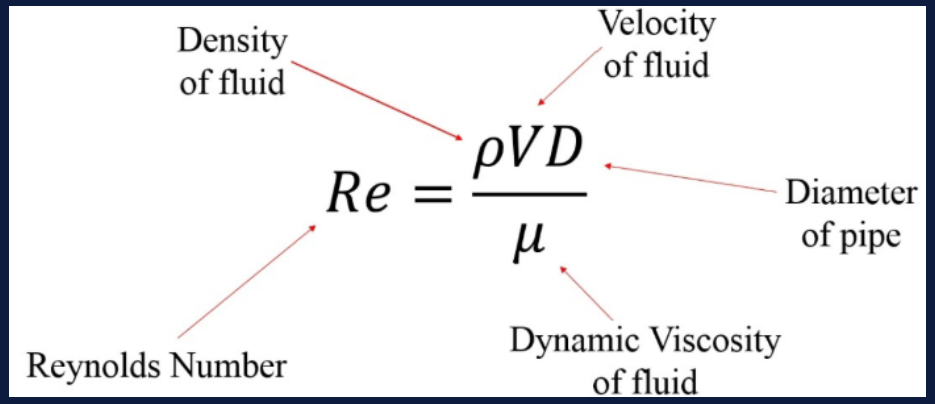
2. Rolling resistance

$$F_{roll} = \mu_r m_b g$$

μ_r : rolling friction coefficient

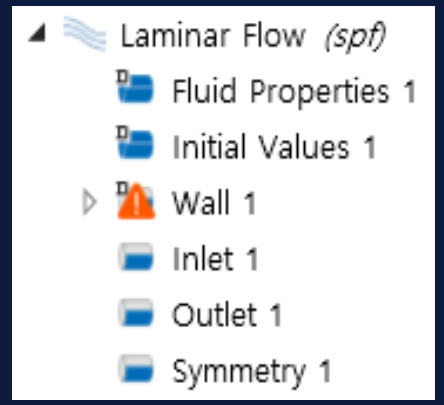
m_b : body mass[kg]

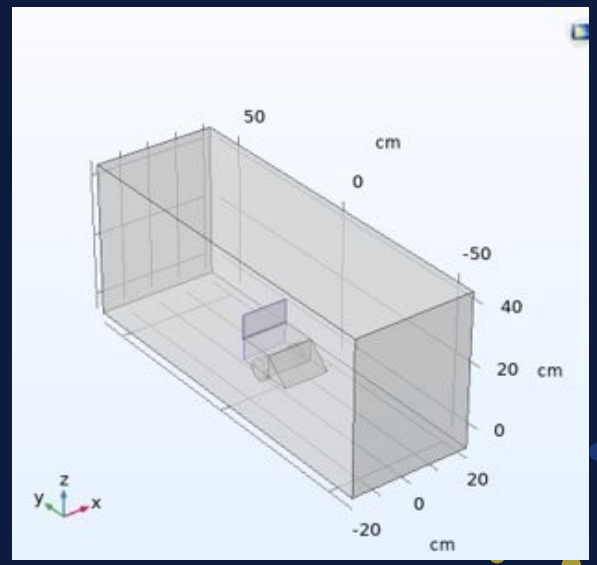
2-1. COMSOL-Drag Force



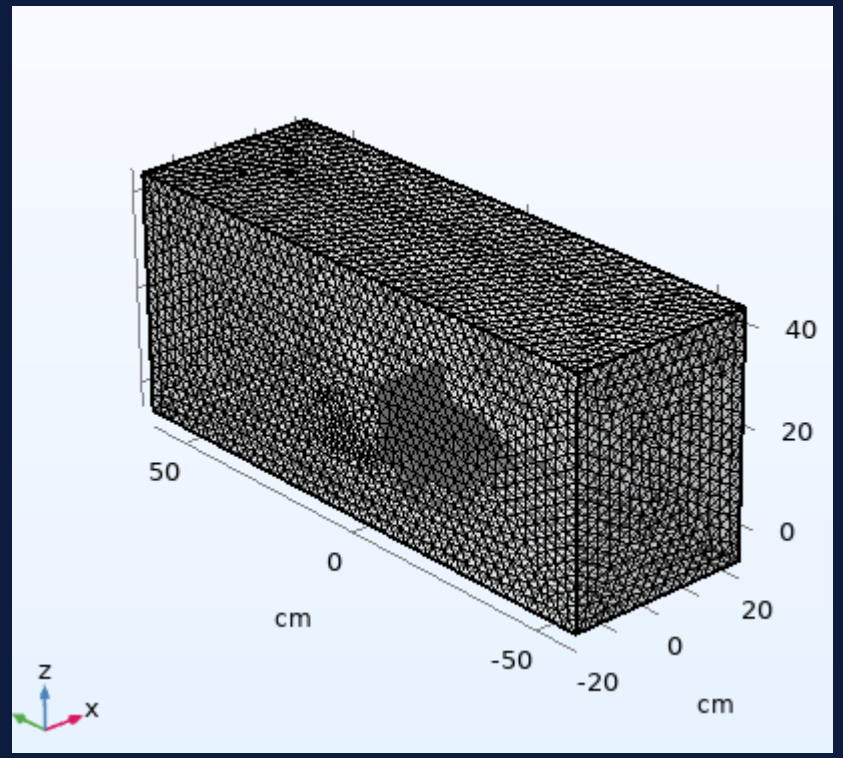
$$Re = \frac{\rho VD}{\mu} = \frac{1.2 \times 40 \times \frac{0.15\sqrt{2}}{2}}{1.515 \times 10^{-5}} = 3.36 \times 10^{5}$$

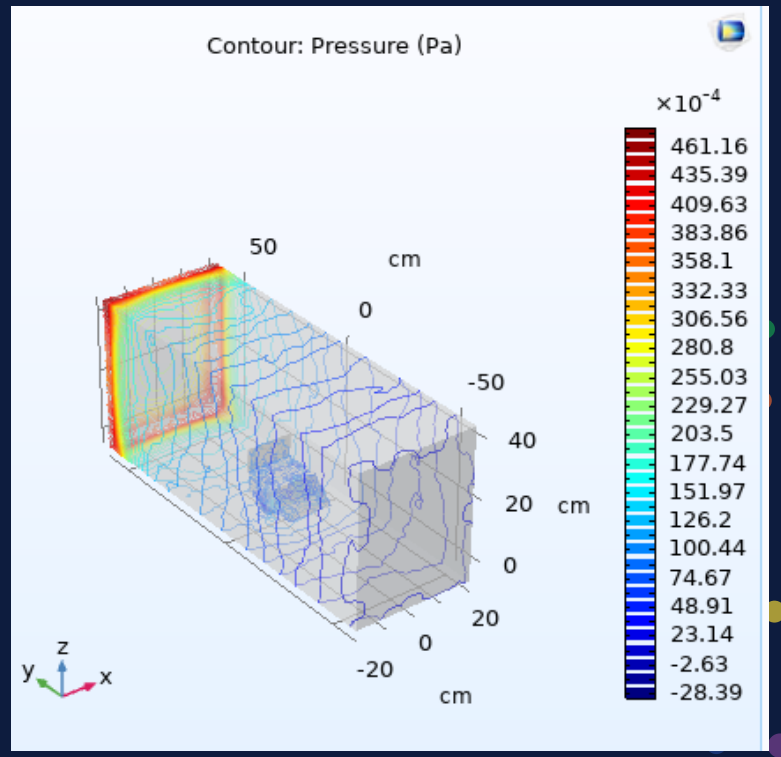
$$Re < 5 \times 10^{5} \rightarrow Laminar\ Flow$$



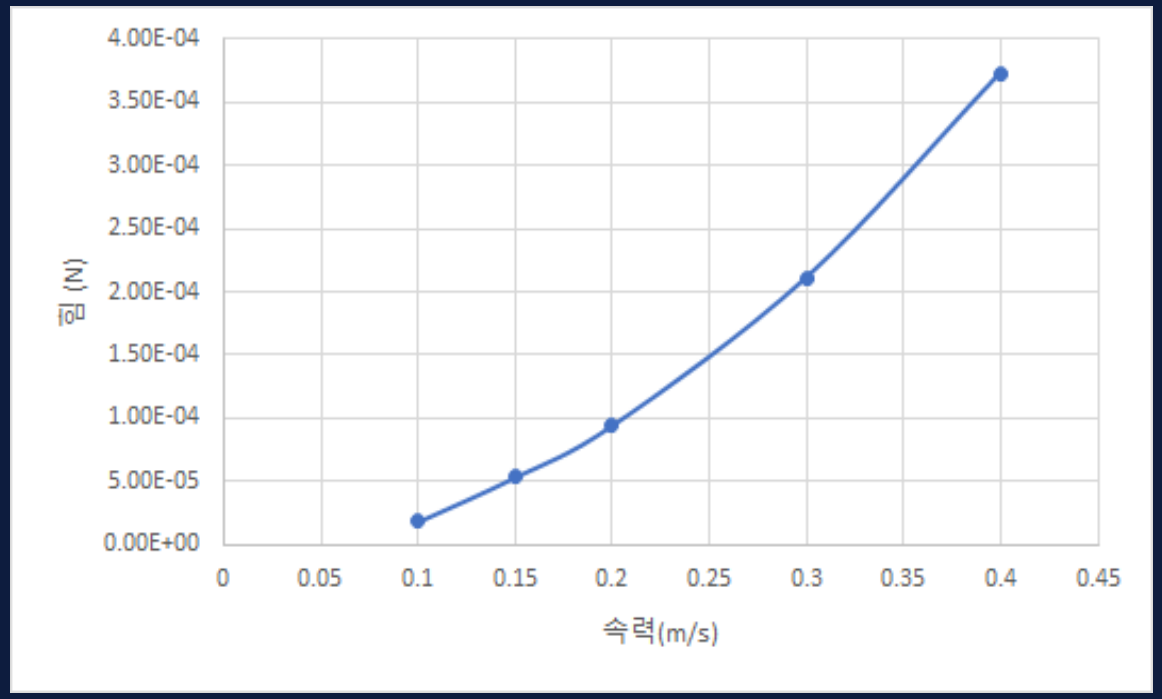


2-1. COMSOL-Drag Force





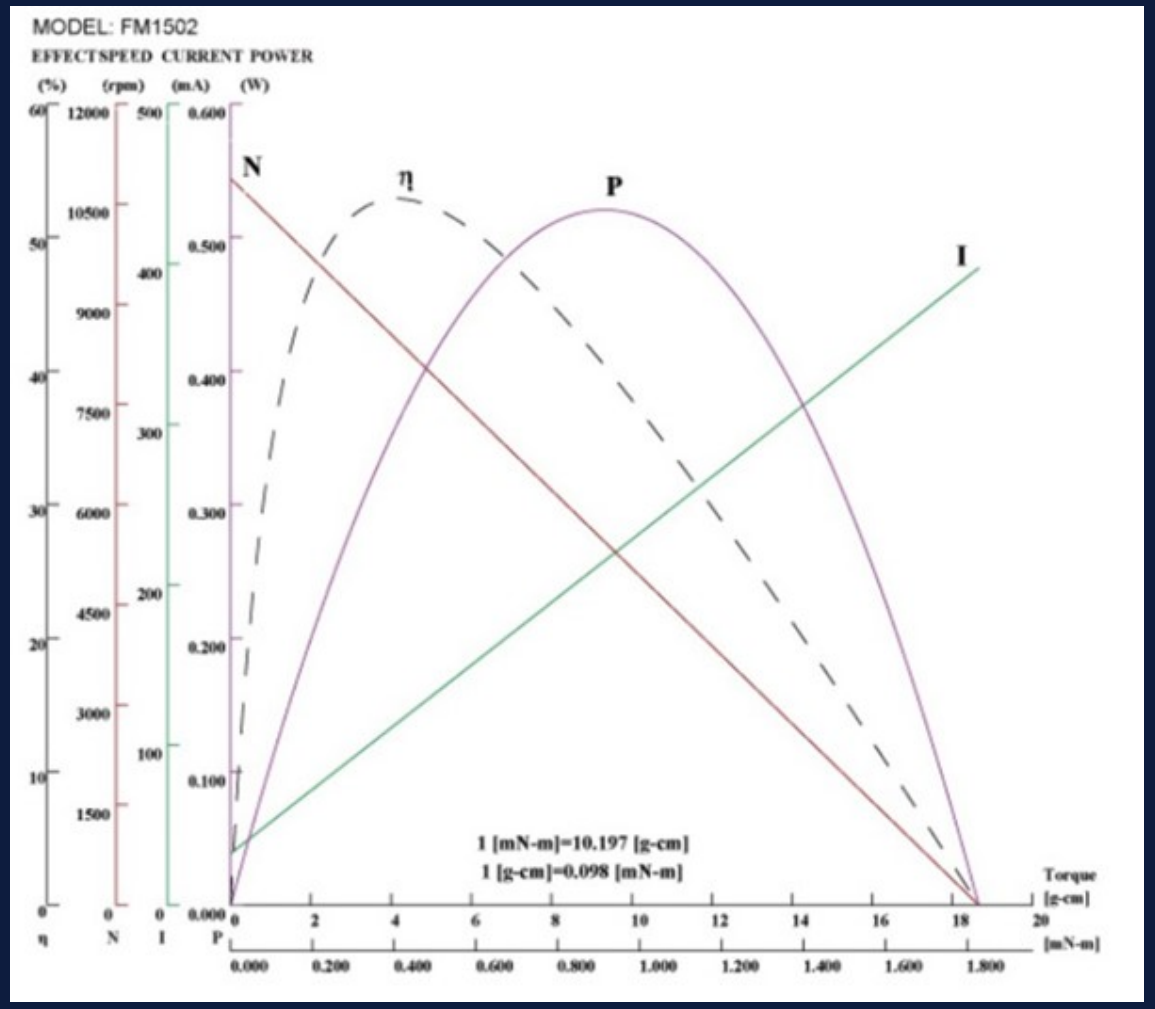
2-1. COMSOL-Drag Force



속력	힘
0.1	1.83E-05
0.15	5.34E-05
0.2	9.45E-05
0.3	2.12E-04
0.4	3.73E-04

2-2. MATLAB&Simulink

2-2. MATLAB&Simulink -NP01D-288 motor



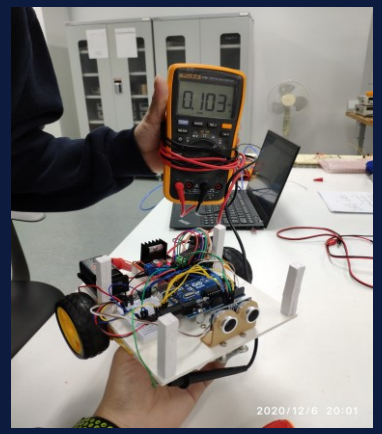
기어박스장착모터 (NP01D-288)

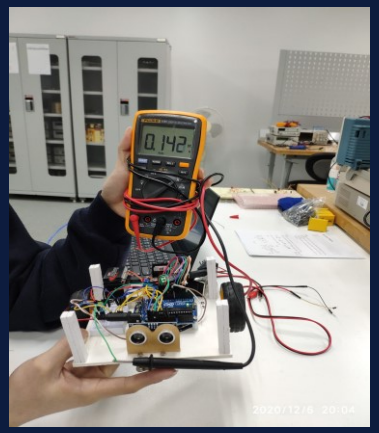
제품사양

1. 기어 비율: 1:288

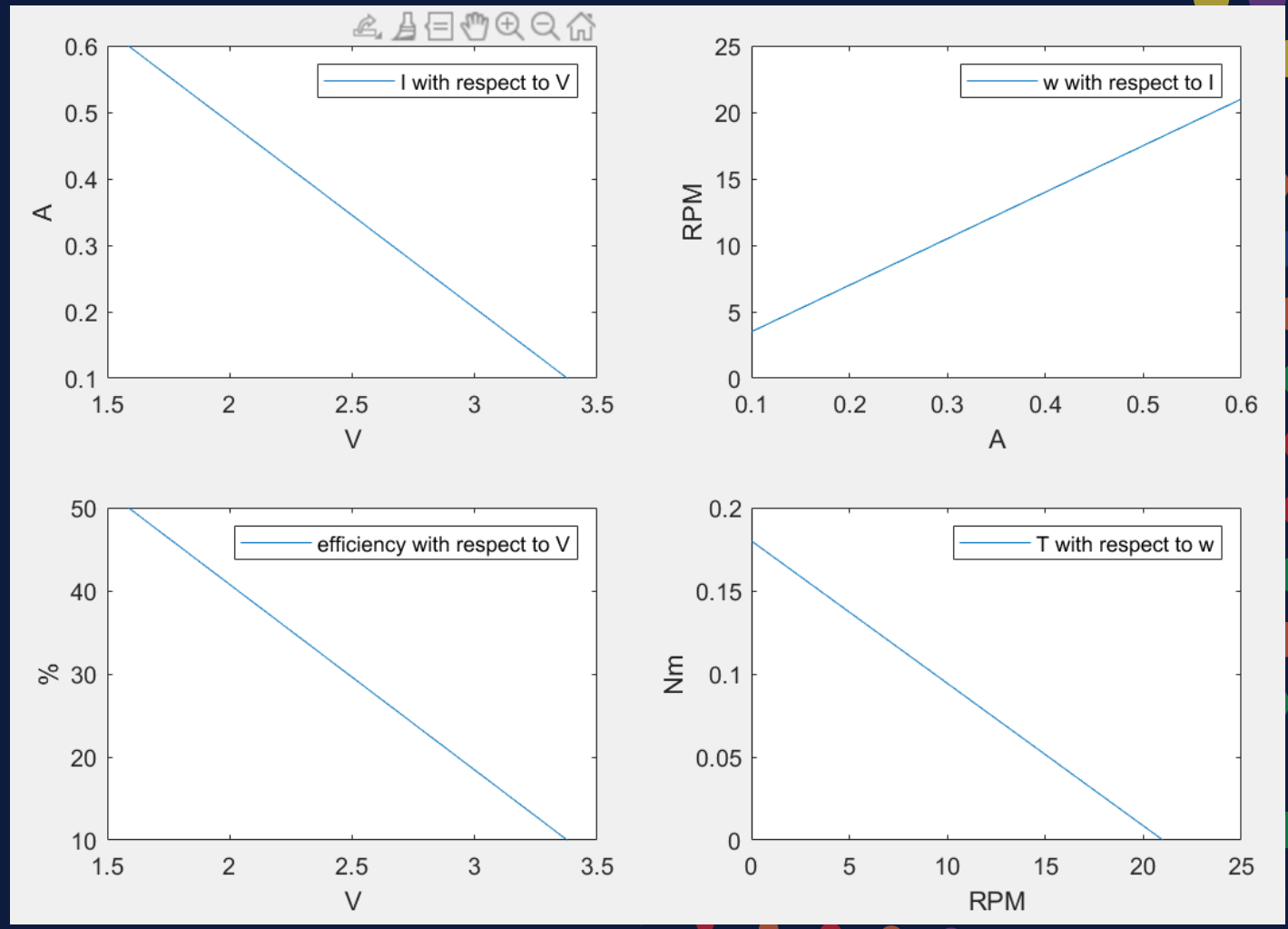
MODEL	VOLTAGE		NO LOAD		AT MAXIMUM EFFICIENCY					STALL		
	OPERATING RANGE	NOMINA	SPEED	CURRENT	SPEED	CURRENT	TORQUE		OUTPUT	TORQUE		CURRENT
		V	r/min	A	r/min	A	N.m	Kg.cm	w	N.m	Kg.cm	A
NP02D -288	3.0 - 12.0	6	21	0.10	19	0.17	0.05	0.47	0.18	0.18	1.8	0.6

Tw = nVI!!

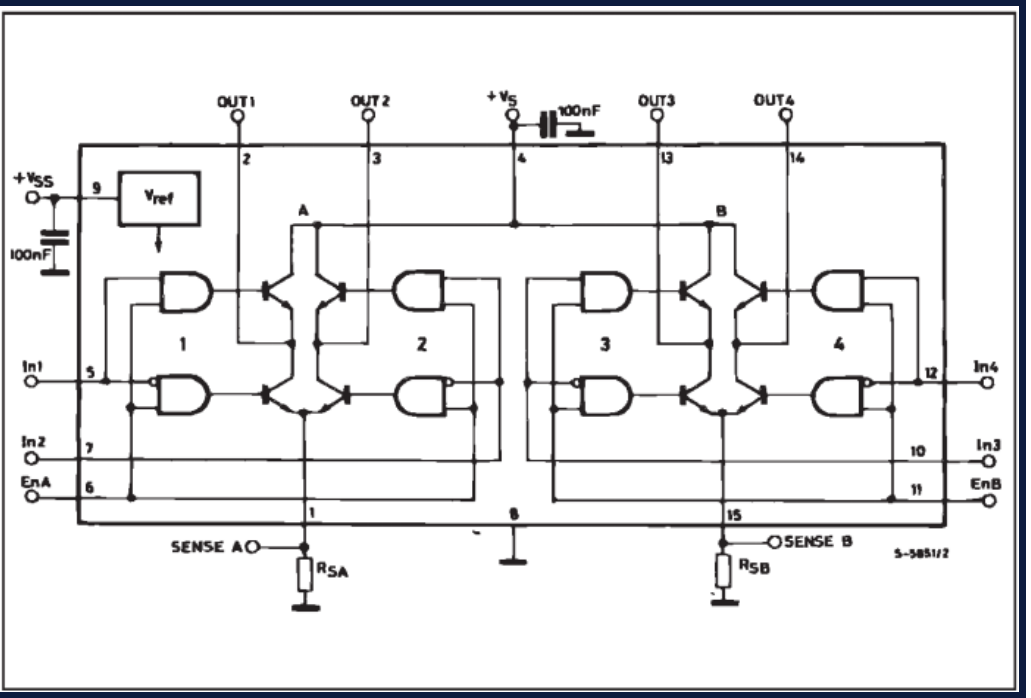


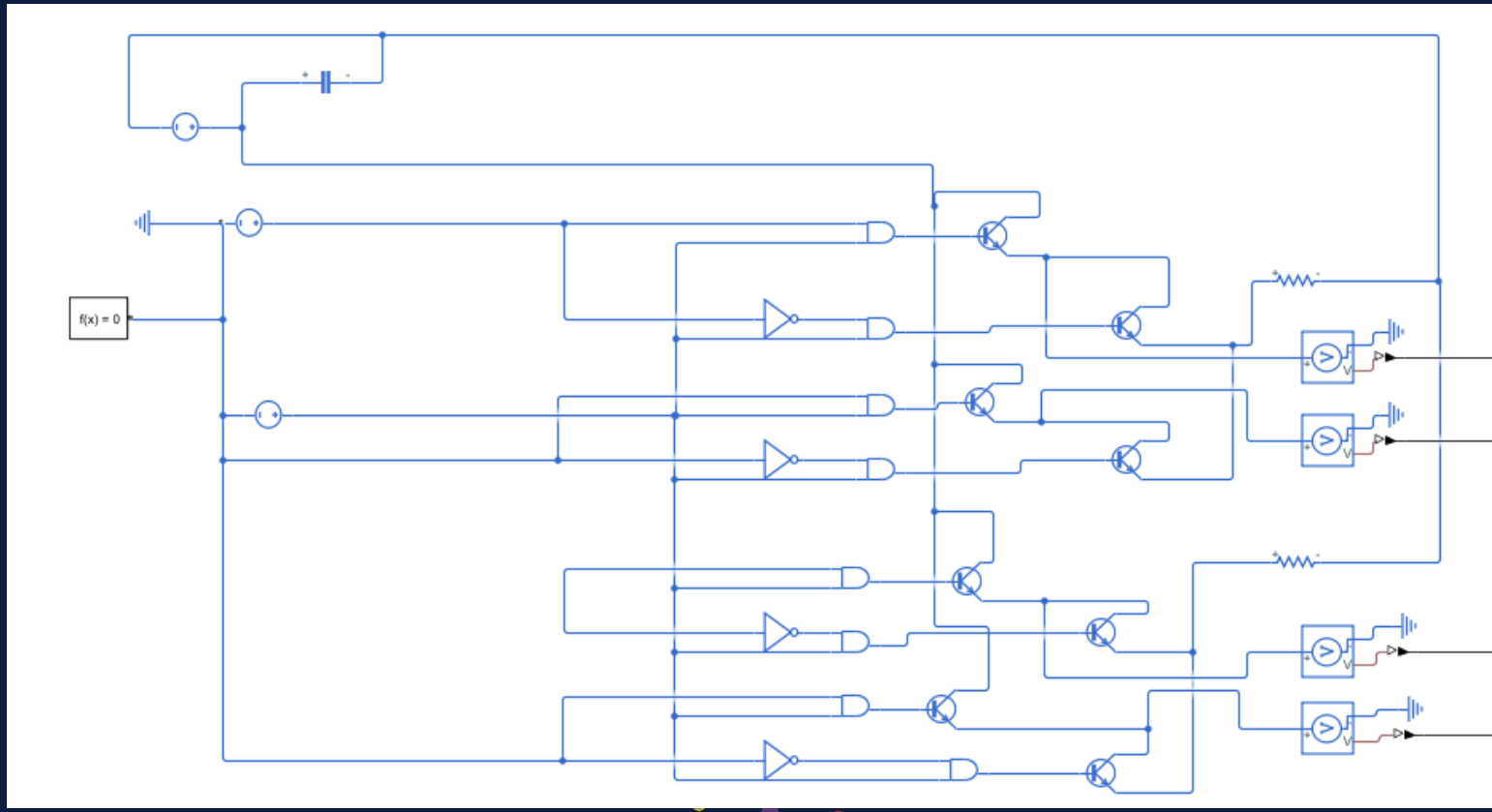


Input Voltage(V)	Output Current(A)
3.378	0.103
3.250	0.142
1.586	0.6

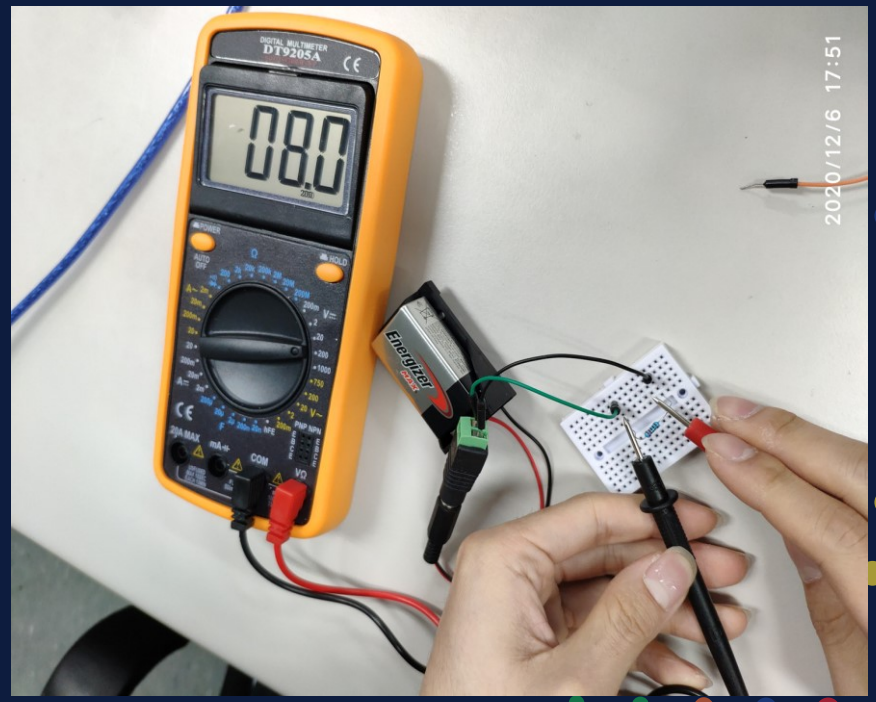


2-2. MATLAB& Simulink-L298n motor driver





2-2. MATLAB&Simulink -Internal Resistance



$$R_{internal} = R_{load} \times \frac{V_{oc} - V_{load}}{V_{load}} = (220\Omega)\left(\frac{8.6V - 8V}{8V}\right) = 16.5\Omega$$

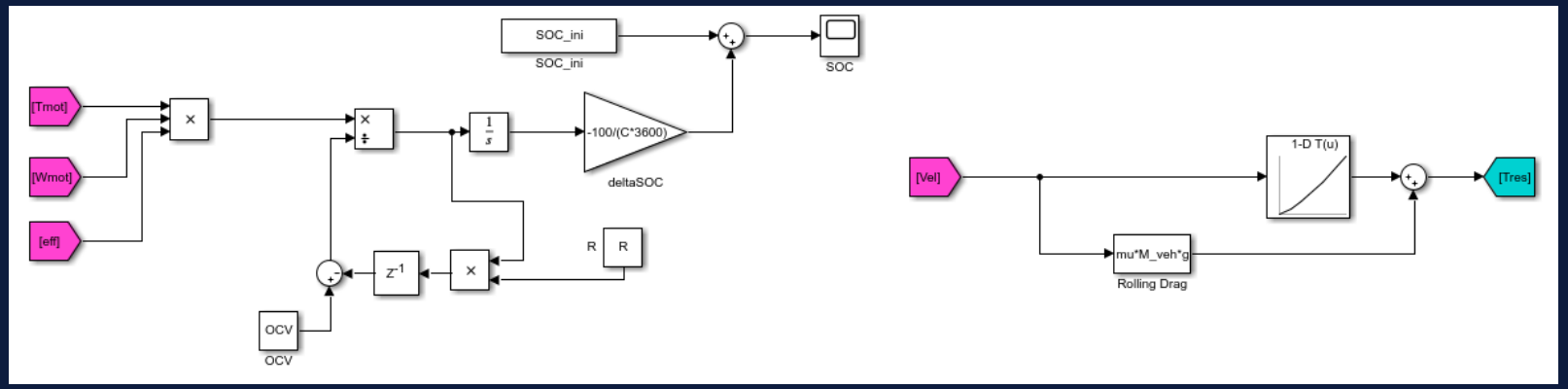
2-2. MATLAB&Simulink -Script

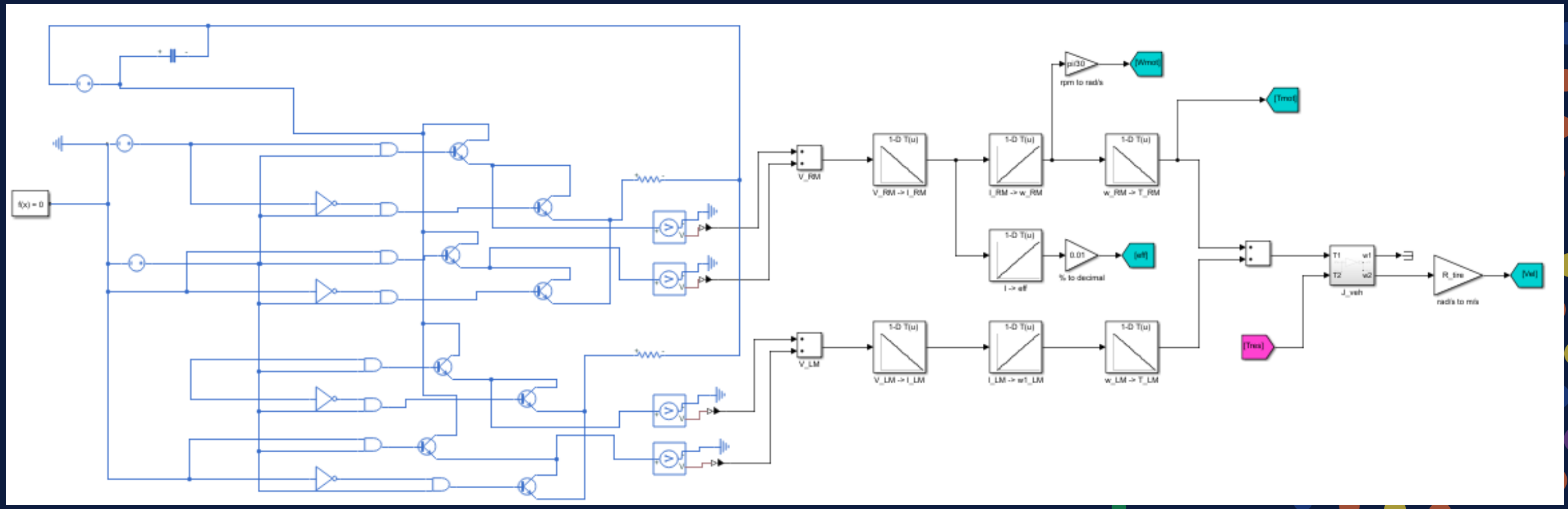
```
clear;
%%Voltage control
V_on = 5;
V_off = 0;
Signal_pwm = 200;
V_pwm = 5*Signal_pwm/255; %V
GND = 0;

%%Vehicle
M_veh = 0.744; %kg
mu = 0.01;
g = 9.81;

%%Drag Force
Vel_input = [0.1, 0.15, 0.2, 0.3, 0.4];
Drag_output = [1.83e-5, 5.34e-5, 9.45e-5, 2.12e-4, 3.73e-4];

%%Battery
SOC_ini = 1;
OCV = 8.6; %V
R = 16.5; %ohm
C = 0.6; %Ah

%%Motor
R_tire = 0.0365; %m
```

```
I_input = linspace(0.1,0.6,20);
I_output = linspace(0.1,0.6,20);
V_input = linspace(3.378,1.586,20);
w_output = linspace(3.5, 21, 20); %rpm
eff_output = linspace(10,50,20);
w_input = linspace(21,0,20); %rpm
T_output = linspace(0,0.18,20);

subplot(2,2,1)
plot(V_input, I_output)
legend('I with respect to V')
xlabel('V'); ylabel('A')
subplot(2,2,2)
plot(I_input, w_output)
legend('w with respect to I')
xlabel('A'); ylabel('RPM')
subplot(2,2,3)
plot(V_input, eff_output)
legend('efficiency with respect to V')
xlabel('V'); ylabel('%')
subplot(2,2,4)
plot(w_input, T_output)
legend('T with respect to w')
xlabel('RPM'); ylabel('Nm')
```

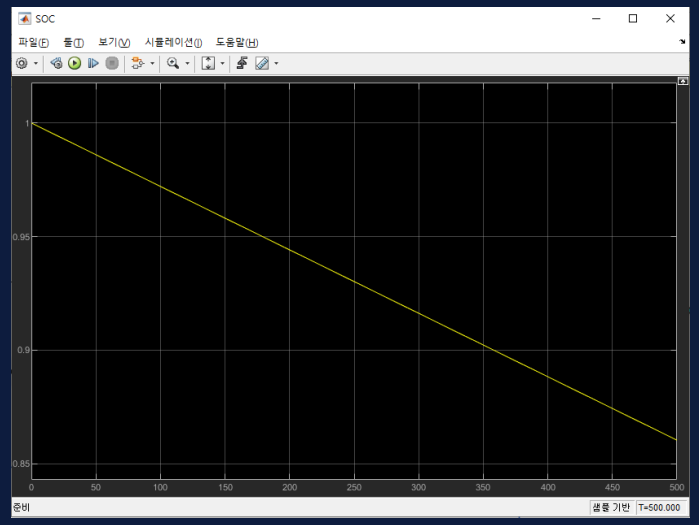
이름	값
C	0.6000
Drag_output	[1.8300e-05,5.3400...
eff_output	*1x20 double*
g	9.8100
GND	0
I_input	*1x20 double*
I_output	*1x20 double*
M_veh	0.7440
mu	0.0100
OCV	8.6000
R	16.5000
R_tire	0.0365
Signal_pwm	200
SOC_ini	1
T_output	*1x20 double*
V_input	*1x20 double*
V_off	0
V_on	5
V_pwm	3.9216
Vel_input	[0.1000,0.1500,0.20...
w_input	*1x20 double*
w_output	*1x20 double*

2-2. MATLAB& Simulink - Model

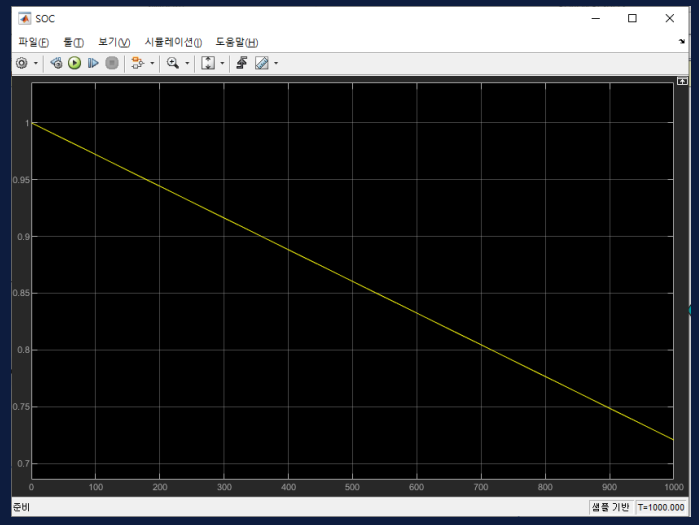




2-2. MATLAB& Simulink –SOC



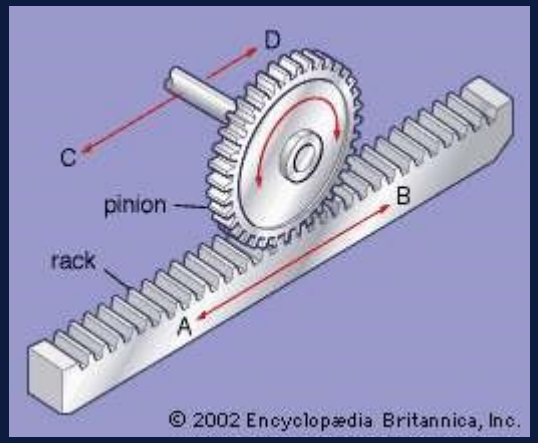
T = 500s



T = 1000s

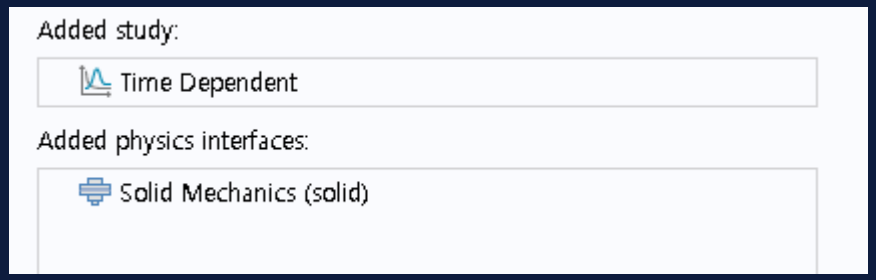
	T = 500s	T = 1000s
Numerical	**Δ0.14**	**Δ0.28**
Actual	**Δ0.22**	**Δ0.42**
Relative error(%)	$\frac{0.22-0.14}{0.22} * 100$ **=36.36%**	$\frac{0.42-0.28}{0.42} * 100$ **=33.33%**

2-3. Introduction - Gear Model



stepping motor
회전운동

직선 운동



2-3. COMSOL - Pushing Force

Parameters

Parameters

Name	Expression	Value	Description
rpm	3000/360	8.3333	
T	15/rpm	1.8	
torque	0.069	0.069	
F	torque/0.0305	2.2623	
f	2*pi/T/4	0.87266	

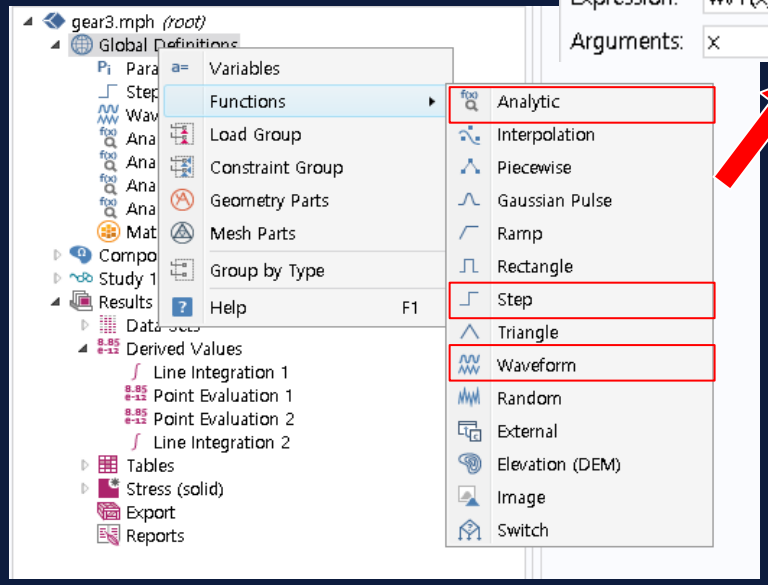
Label: Analytic 1

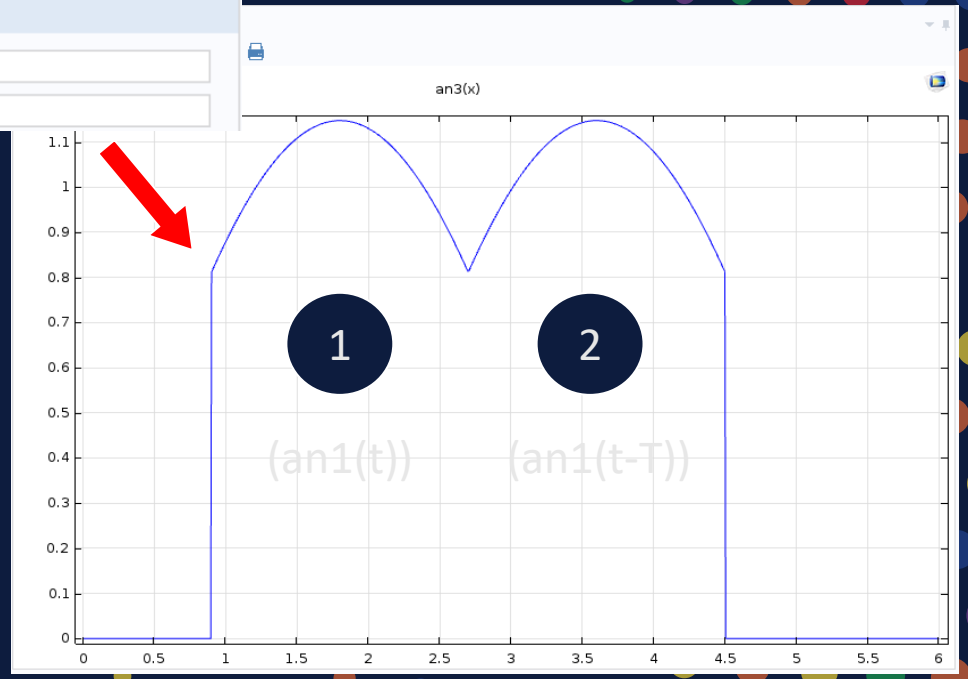
Function name: an1

Definition

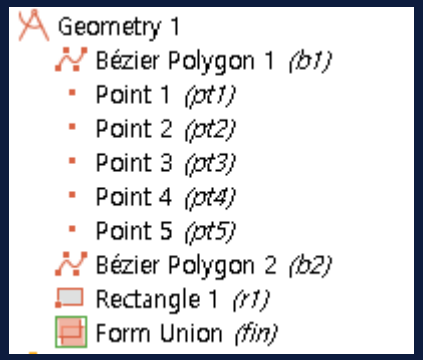
Expression: ww1(x)*(step(x-T/2)-step(x-3*T/2))

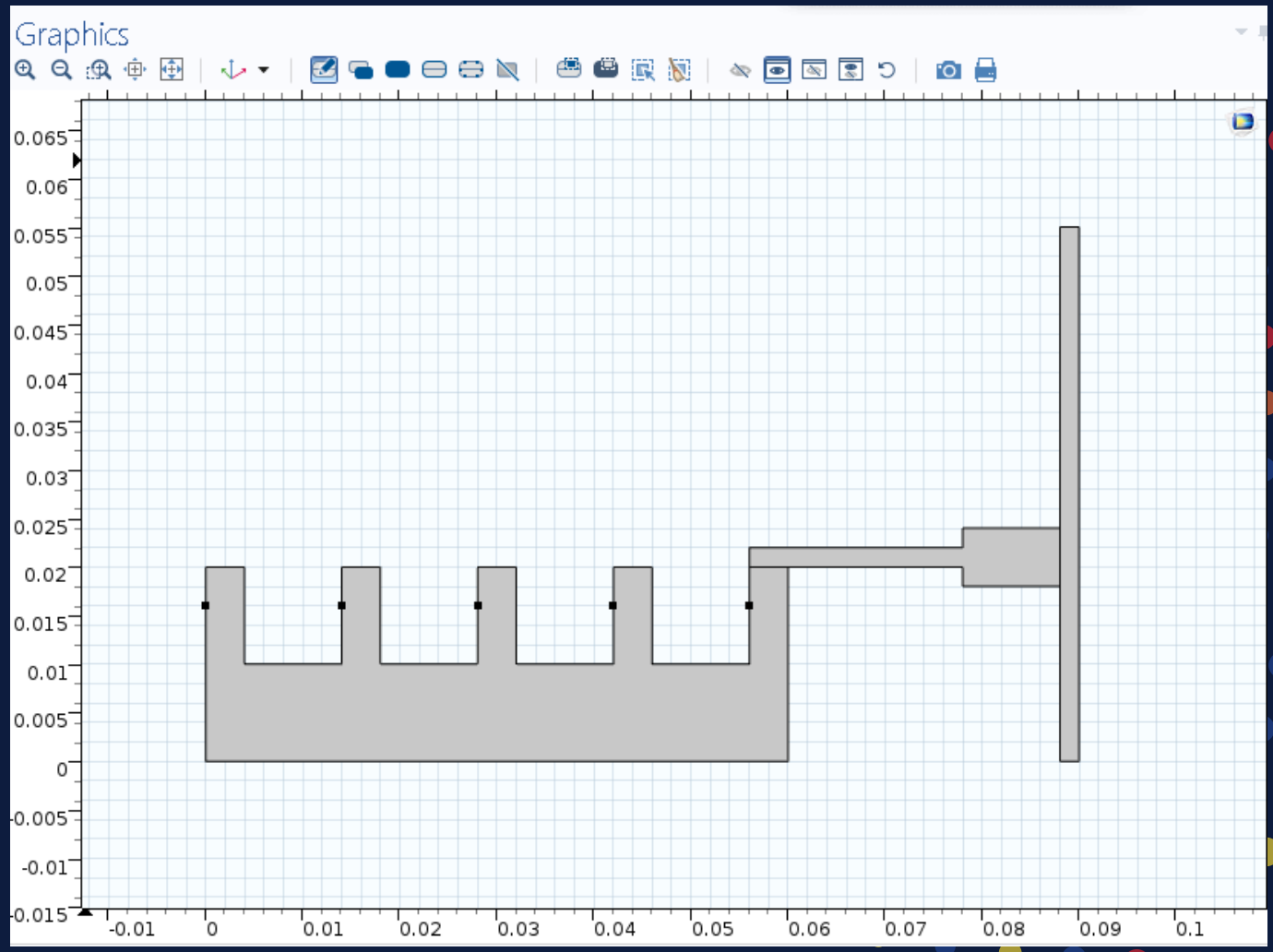
Arguments: x



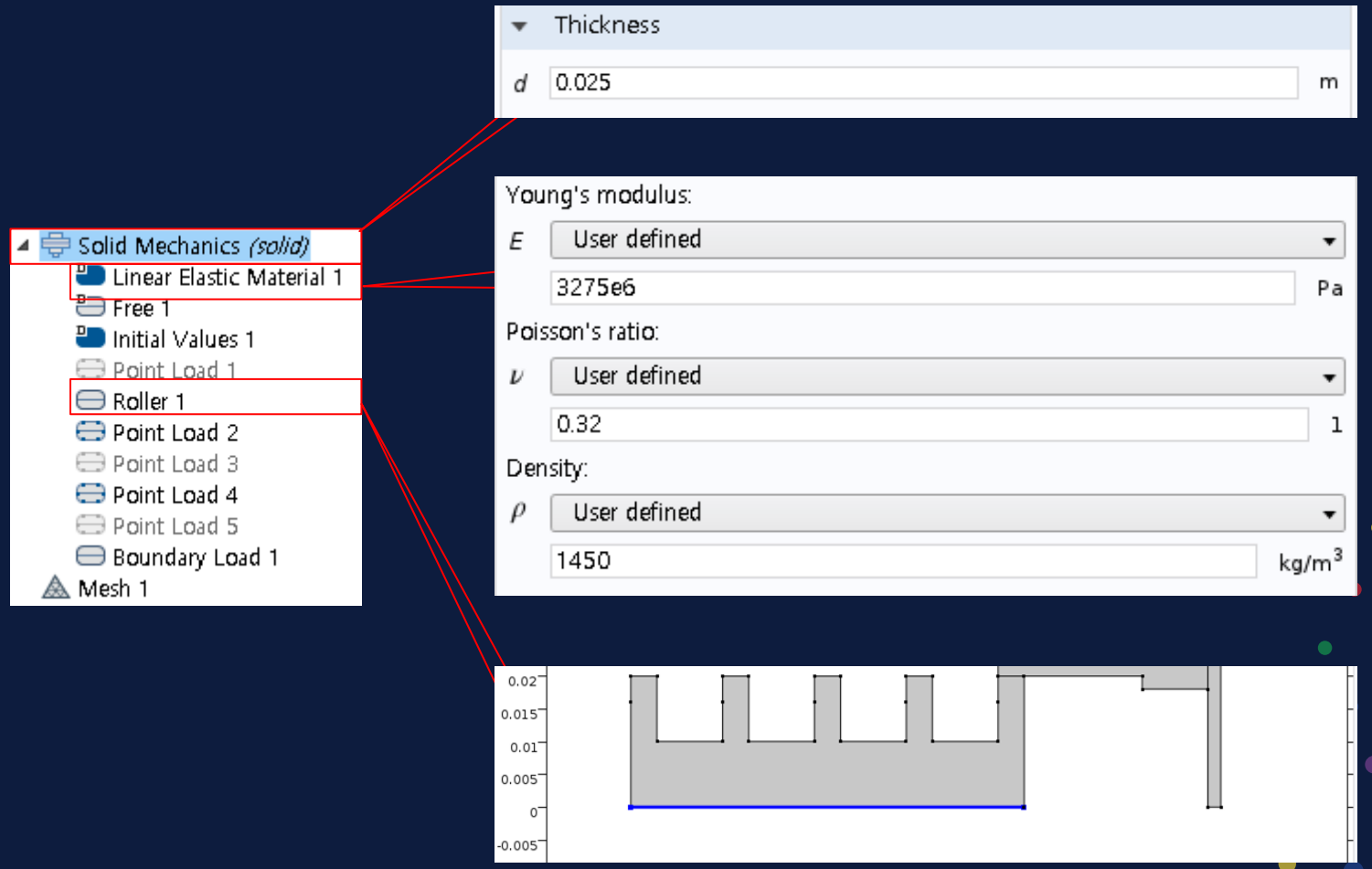


2-3. COMSOL - Pushing Force

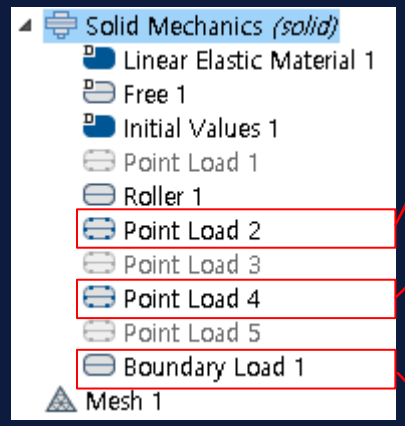


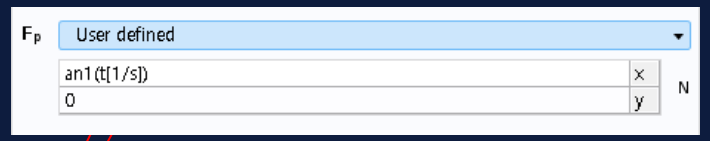


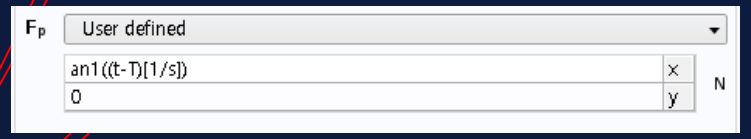
2-3. COMSOL - Pushing Force

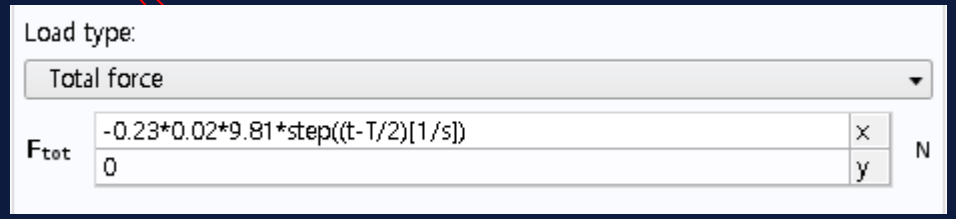


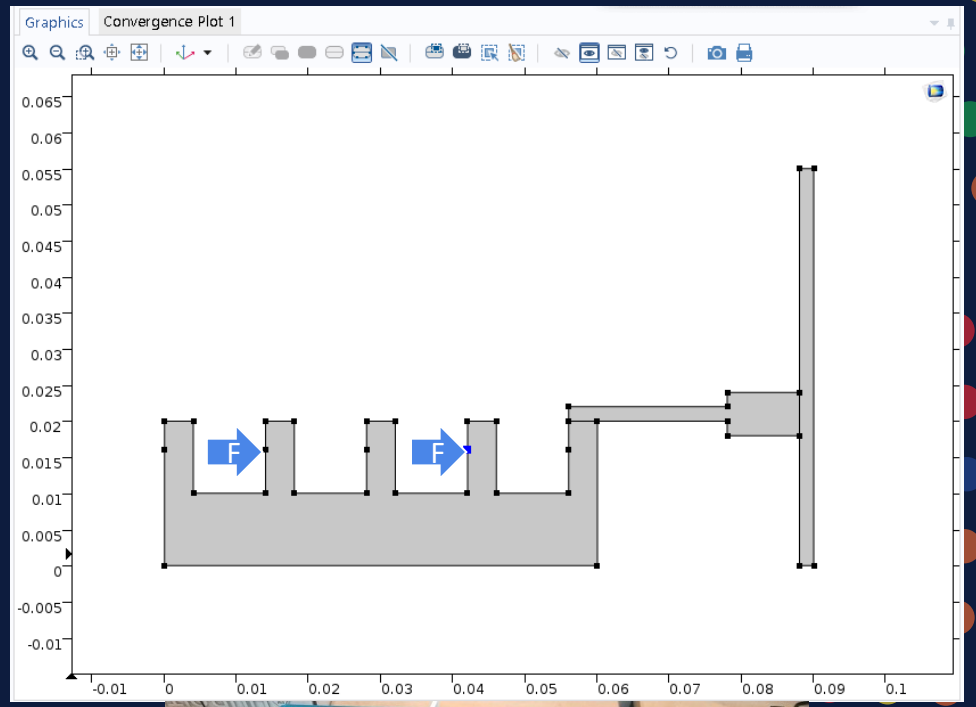
2-3. COMSOL - Pushing Force

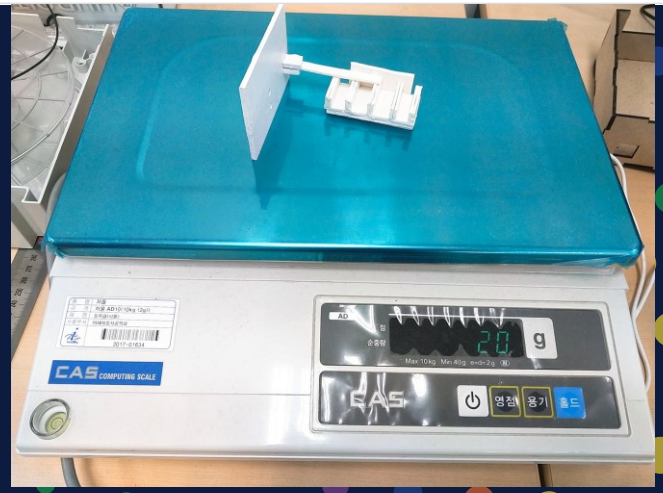




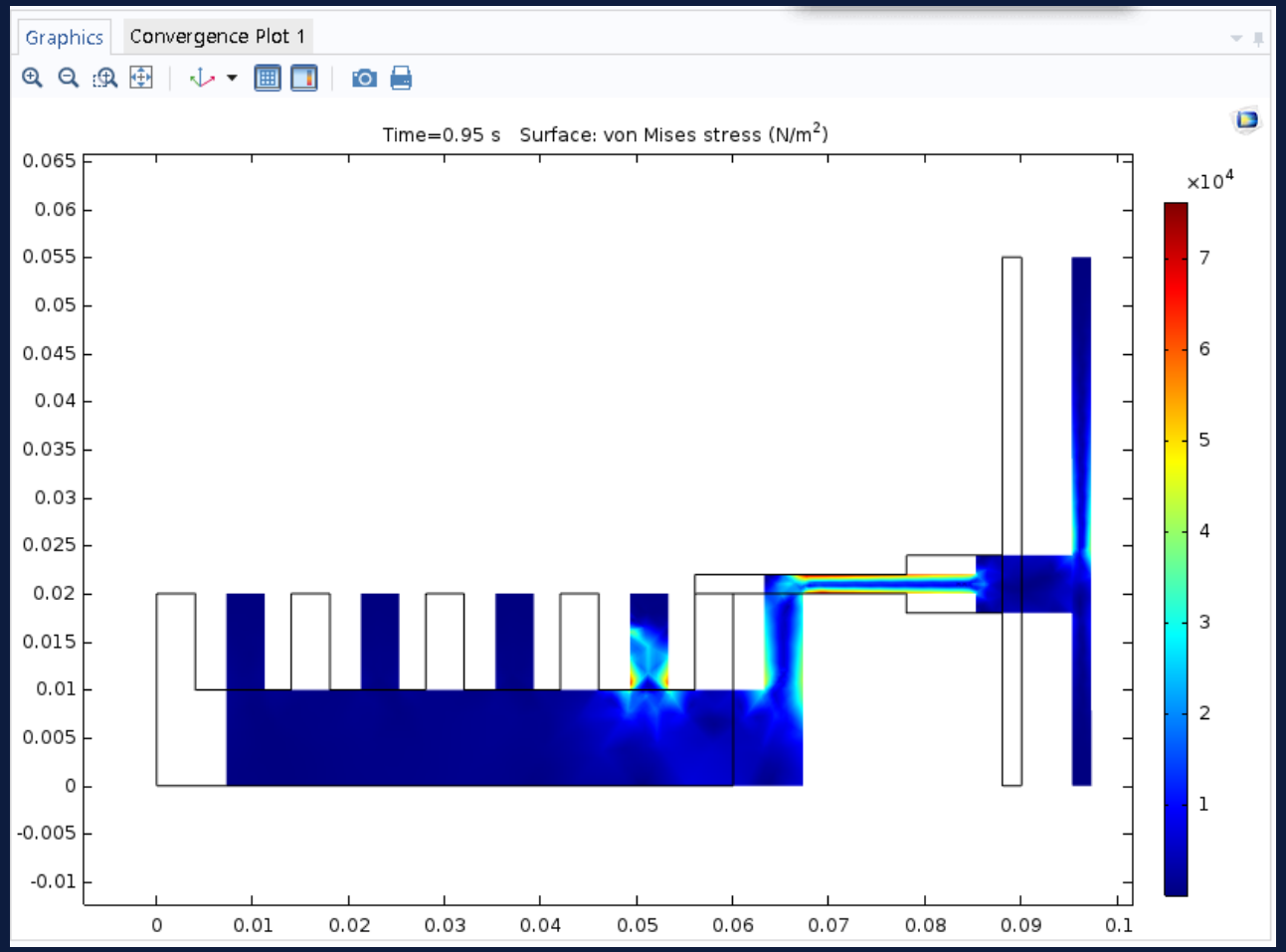








2-3. Result & Comparison - Numerical



Messages | Progress | Log | Table 3

Time (s)	Stress tensor, x component (N/m)
0.90000	0.0000
1.0000	12.551
1.1000	13.751
1.2000	14.390
1.3000	15.052
1.4000	15.653
1.5000	16.109
1.6000	16.421
1.7000	16.618
1.8000	16.683
1.9000	16.619
2.0000	16.424
2.1000	16.107
2.2000	15.650
2.3000	15.115
2.4000	14.392
2.5000	13.670
2.6000	12.734
2.7000	11.697
2.8000	11.496
2.9000	13.492
3.0000	15.485
3.1000	15.357
3.2000	15.671
3.3000	16.096
3.4000	16.422
3.5000	16.616
3.6000	16.695
3.7000	16.618
3.8000	16.425
3.9000	16.107
4.0000	15.661
4.1000	15.084
4.2000	14.399
4.3000	13.604
4.4000	12.704
4.5000	11.693
4.6000	-0.29999

Average of line integral 16[N/m]

Max Pushing Force (16*0.075) = Friction Force (0.45*m*9.81)

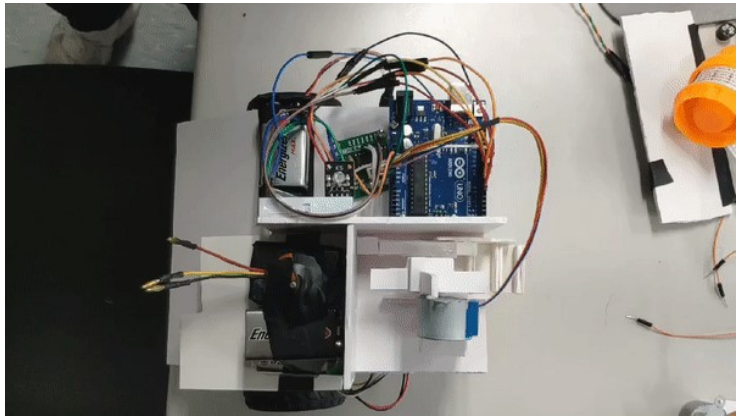
m=271g

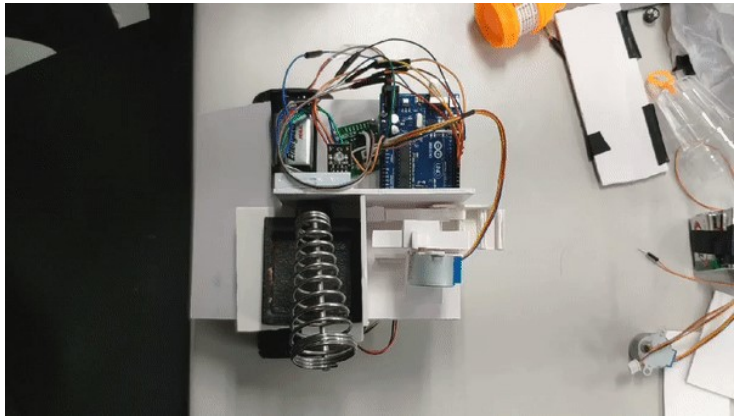
2-3. Result & Comparison - Real

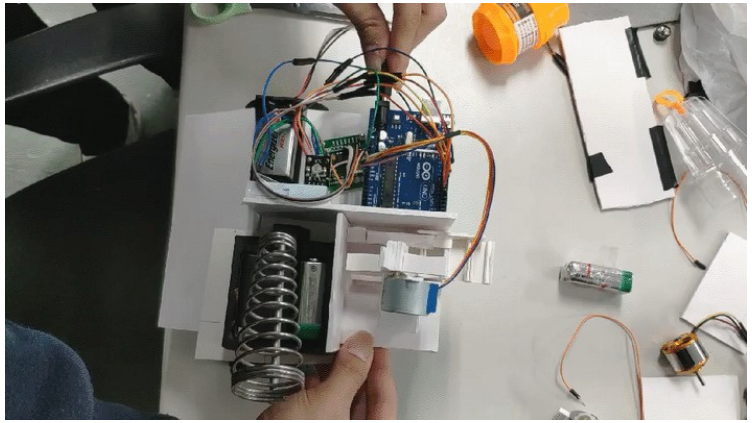
O

O

X







References

- L298n datasheet - STMicroelectronics
- Energizer 9V max datasheet - https://data.energizer.com/
- https://www.devicemart.co.kr/goods/view?no=37853co.kr
- “The Internal Resistance of a battery - A Physical Perspective” - Ashok K. Singal
- “Airflow Over and Ahmed Body” - COMSOL Multiphysics 5.4

Thank You For Listening!