

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

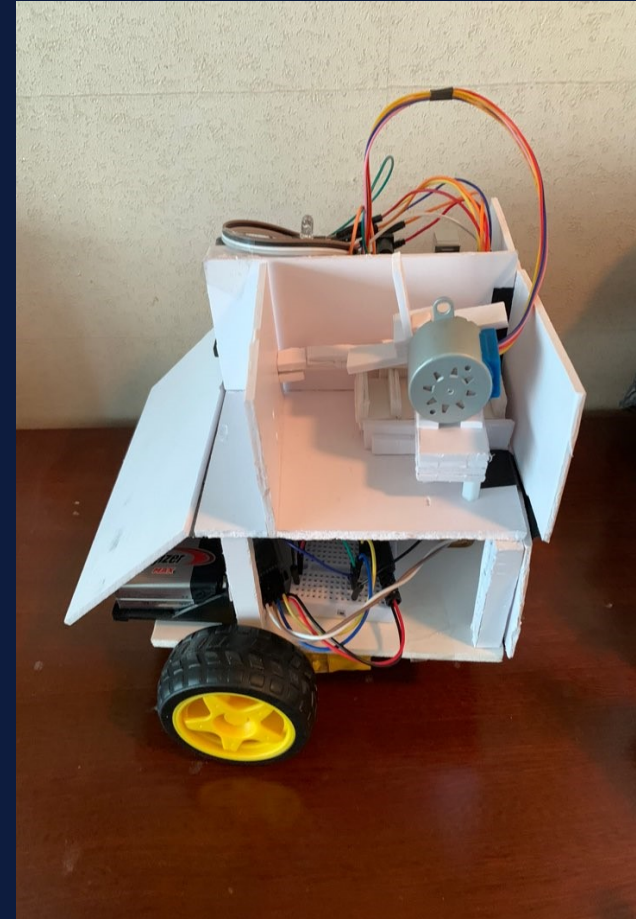
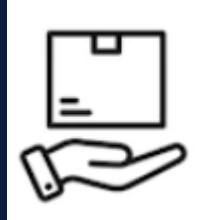
1. Background

Why did we choose this?



1. Background

- Robot that delivers parcels from one floor to another
- **Know Yourself!!**
- Compare **Numerical and Actual** results

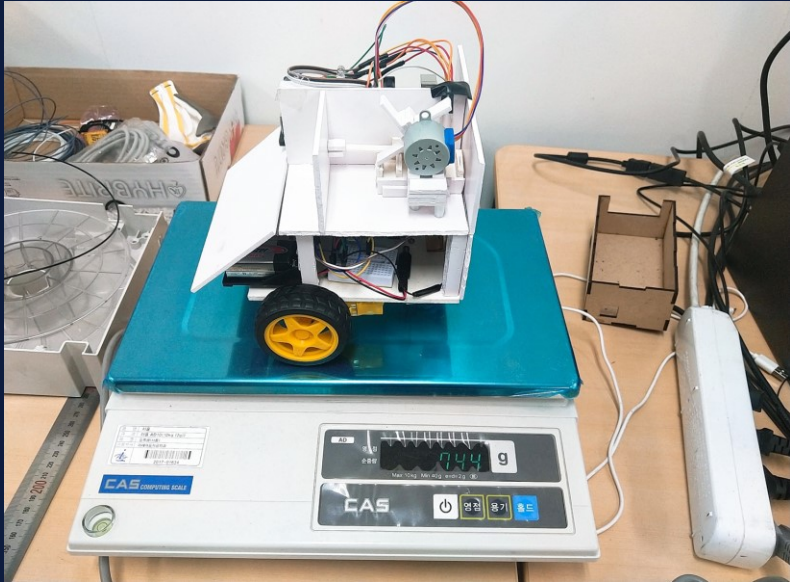


The background of the slide is a dark blue field filled with a dense pattern of small, multi-colored dots. The dots are scattered across the entire area, with a slight concentration in the center. The colors of the dots include red, yellow, green, blue, purple, and orange. The overall effect is a vibrant, textured background.

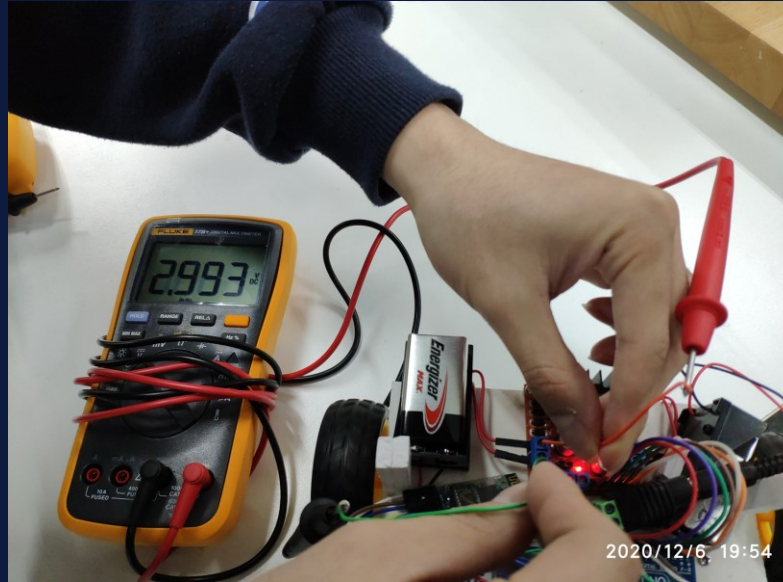
2. Simulation

To Obtain Numerical Result

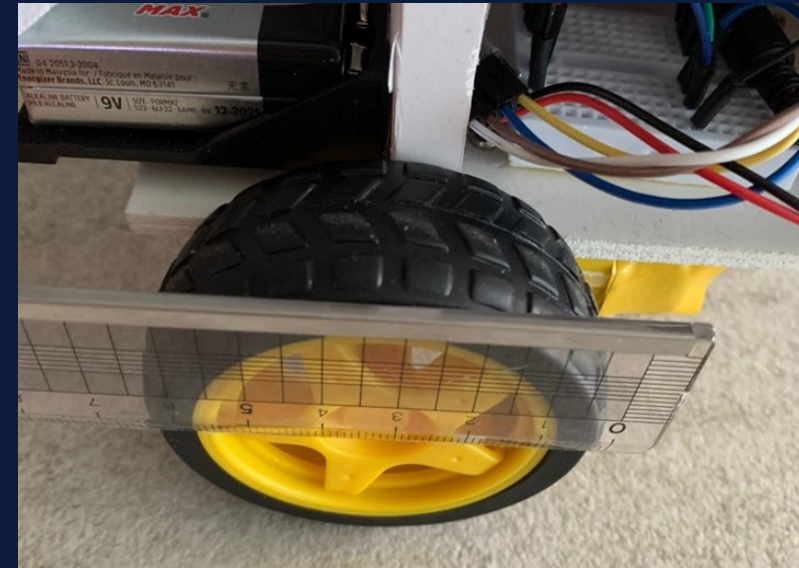
2. Specifications



Vehicle mass

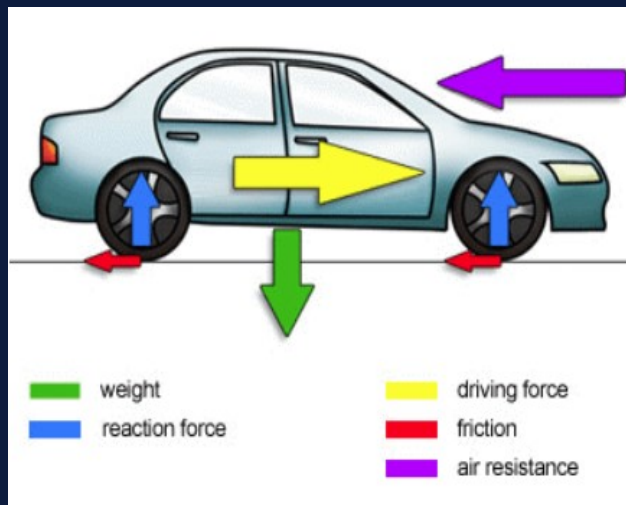
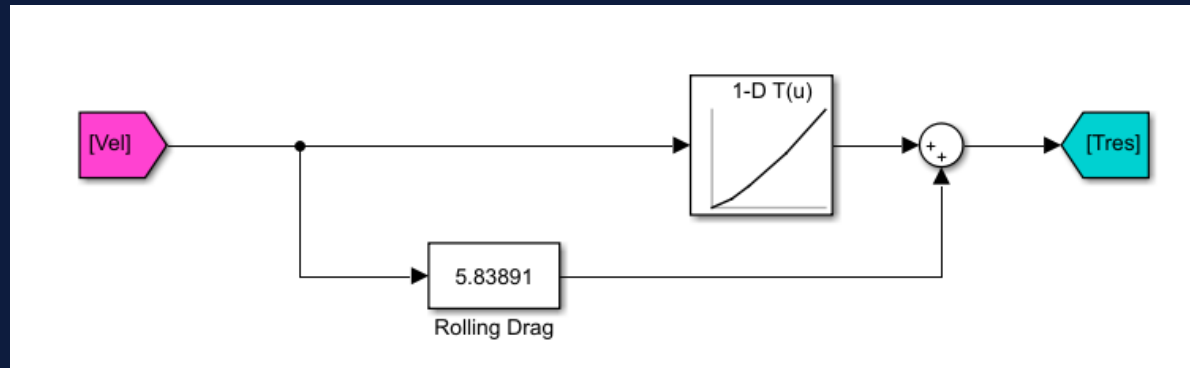


V_{bat}



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 [m²]

ρ_{air} : air density [kg/m³]

V_{veh} : vehicle speed [m/s²]

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

$$Re = \frac{\rho V D}{\mu}$$

Density of fluid

Velocity of fluid

Diameter of pipe

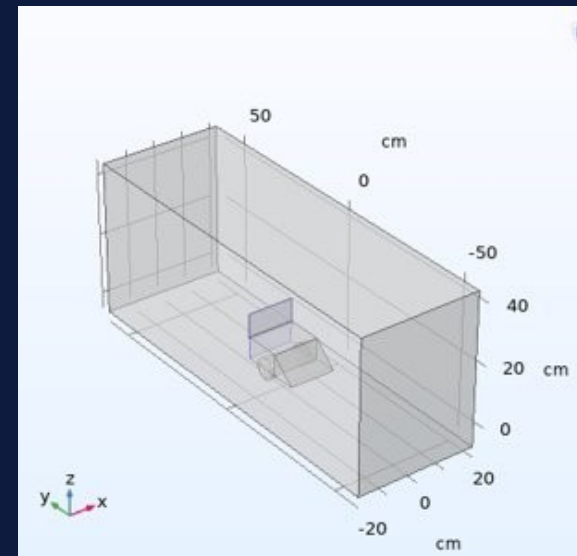
Dynamic Viscosity of fluid

Reynolds Number

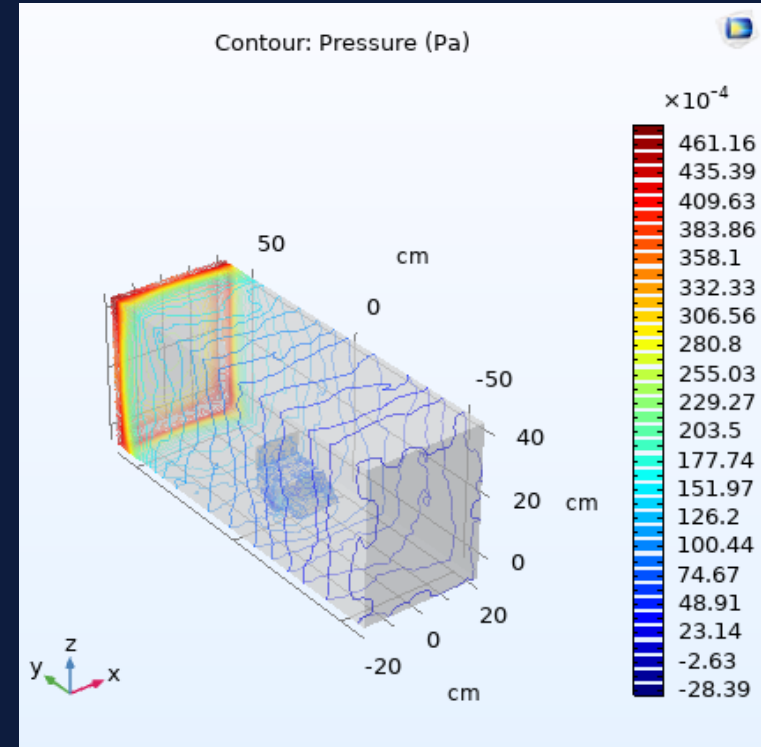
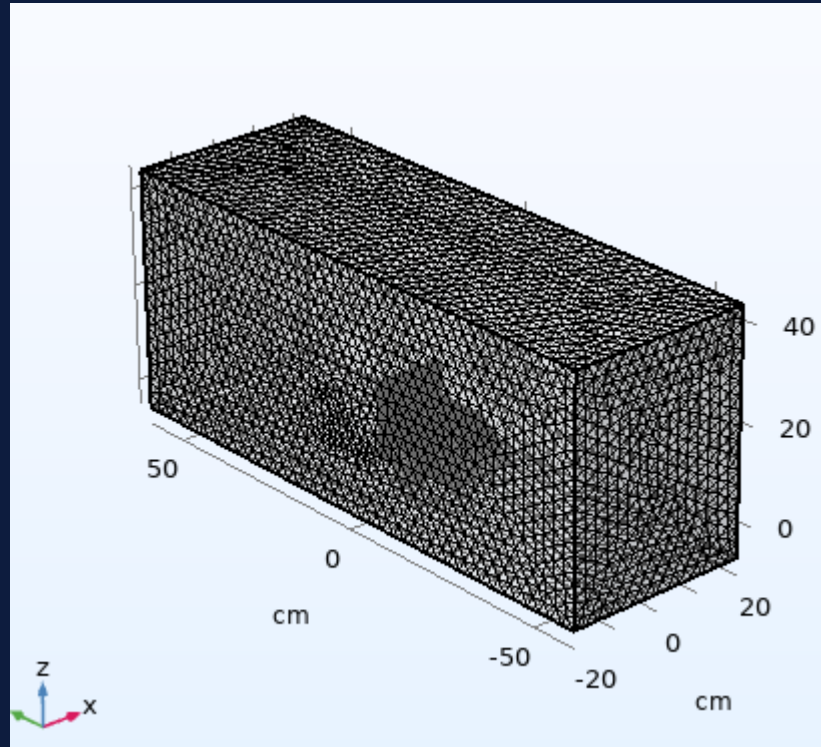
$$Re = \frac{\rho V D}{\mu} = \frac{1.2 \times 40 \times \frac{0.15 \sqrt{2}}{2}}{1.515 \times 10^{-5}} = 3.36 \times 10^5$$

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

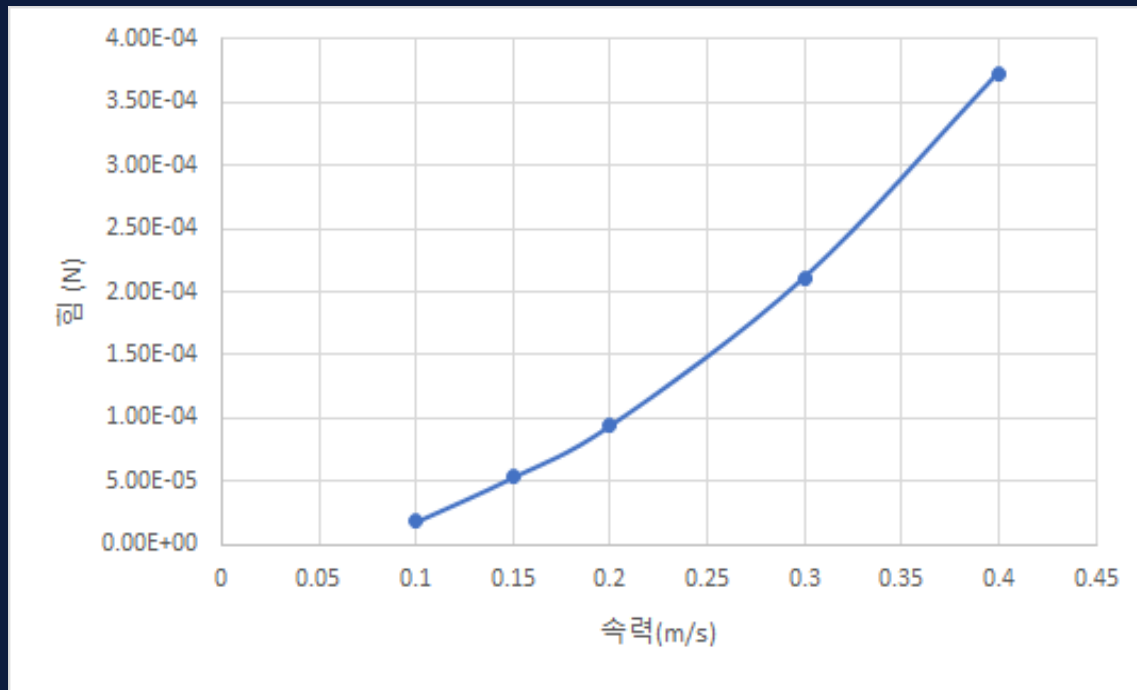
- Laminar Flow (*spf*)
- Fluid Properties 1
- Initial Values 1
- Wall 1
- Inlet 1
- Outlet 1
- Symmetry 1



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

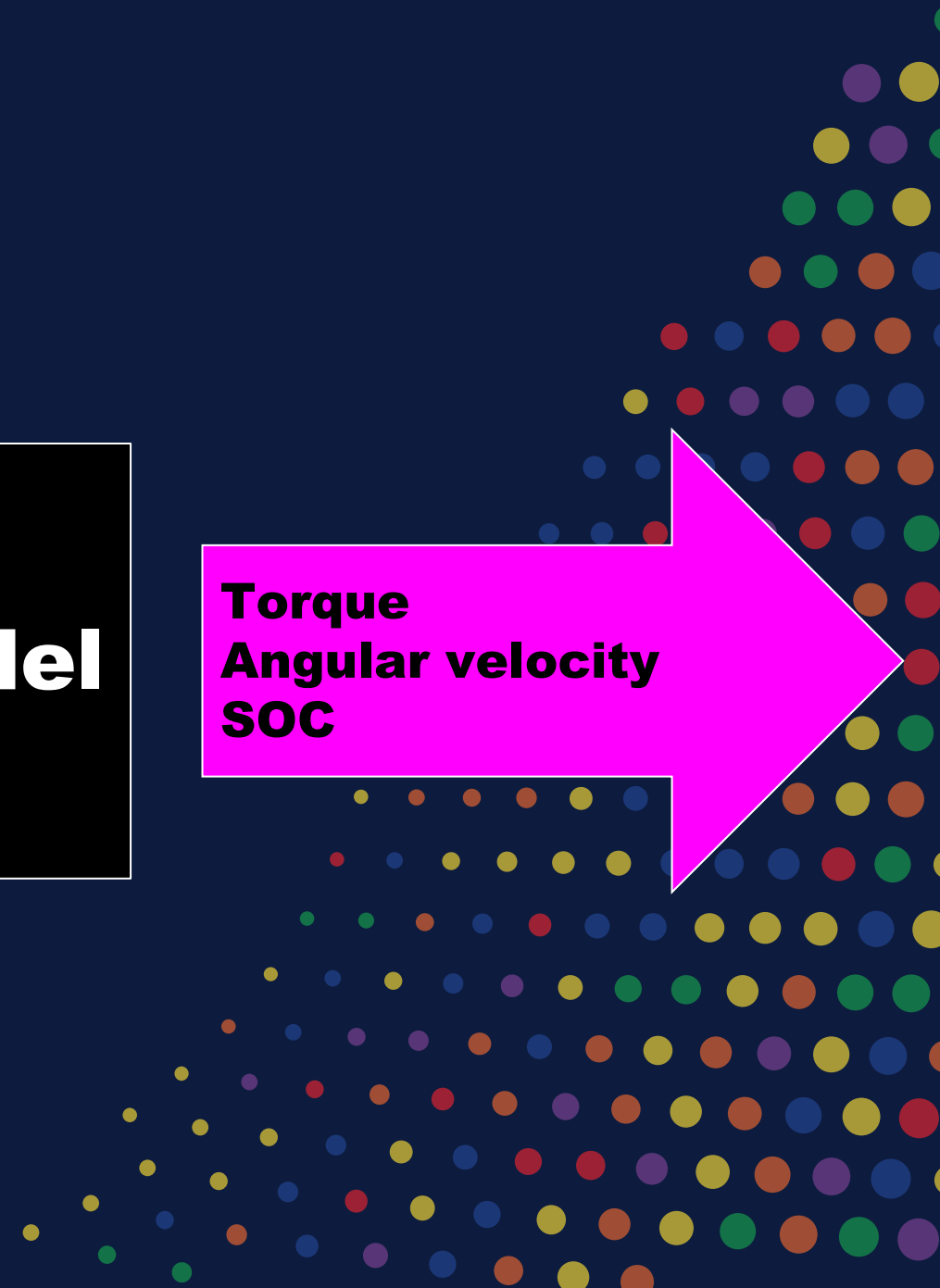
2-2. MATLAB&Simulink

Battery voltage

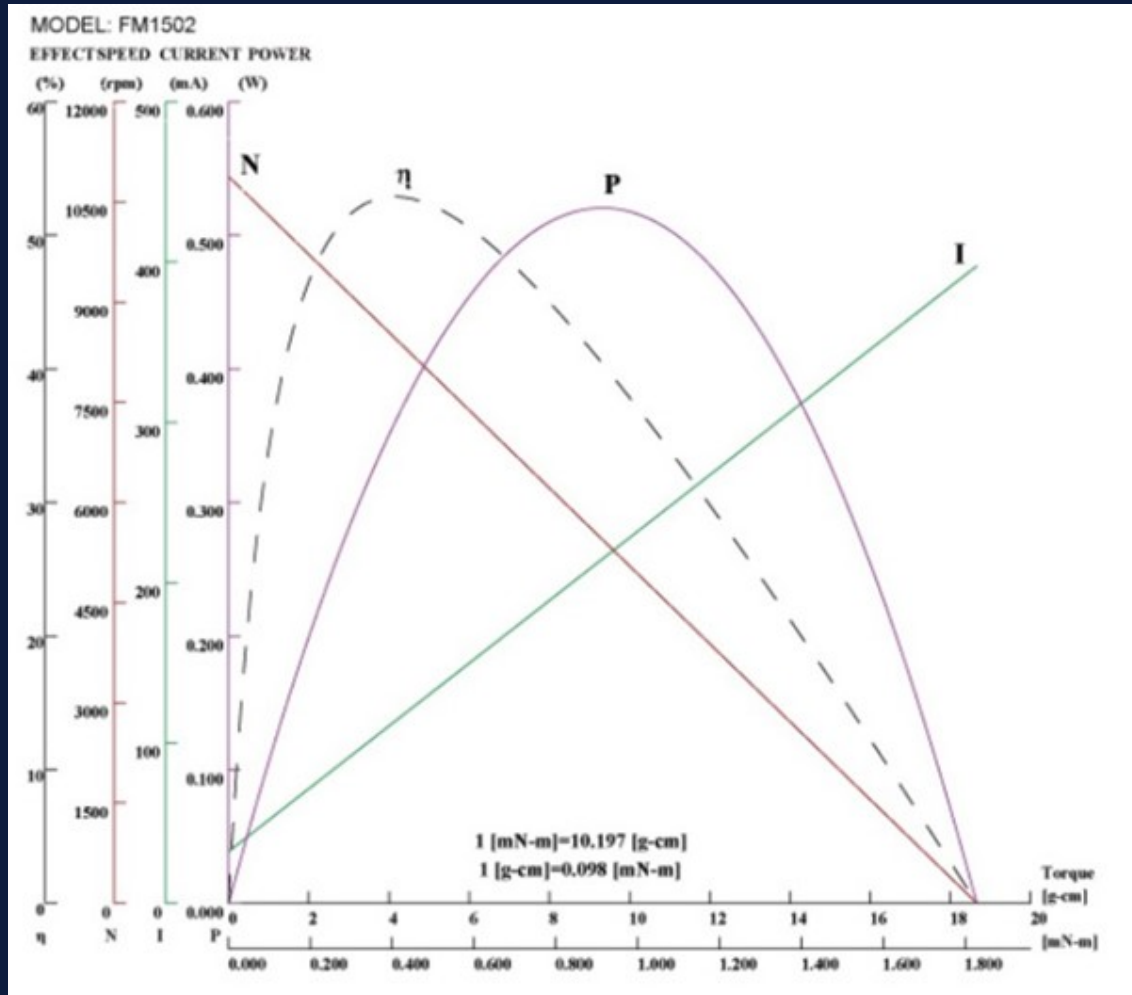
**(i) 5V digital output
(ii) pwn signal
from Arduino board**

Simulink Model

**Torque
Angular velocity
SOC**



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



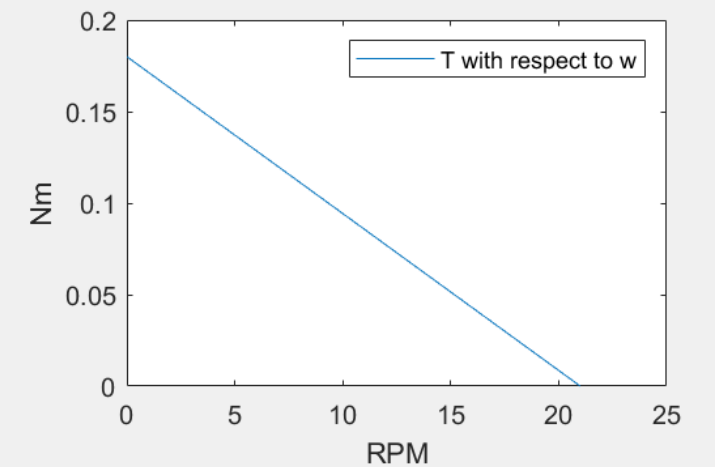
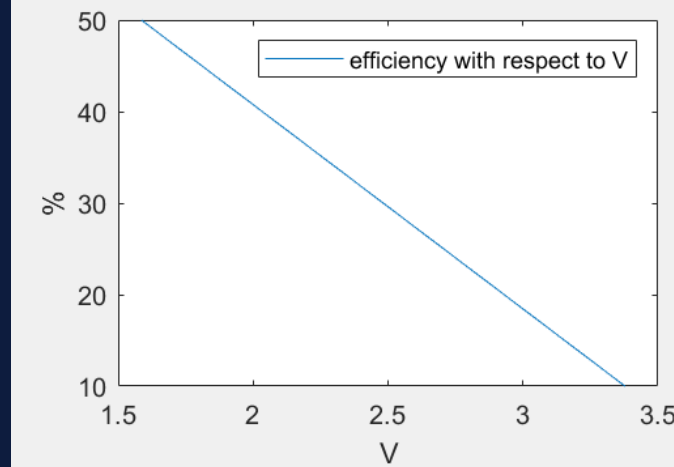
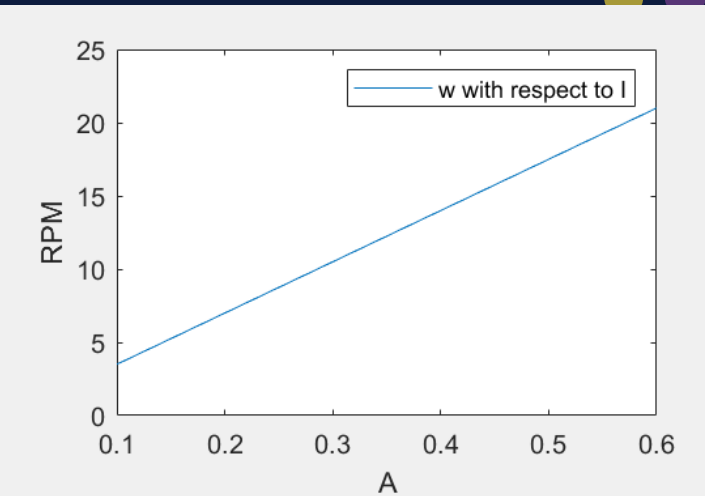
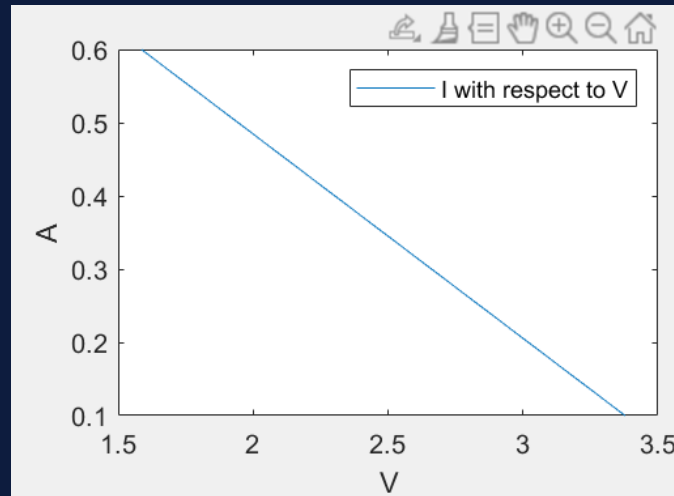
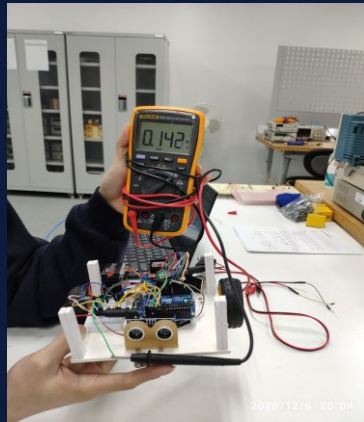
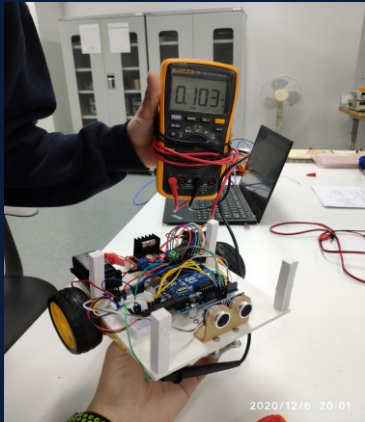
기어박스장착모터 (NP01D-288)

제품사양

1. 기어 비율: 1:288

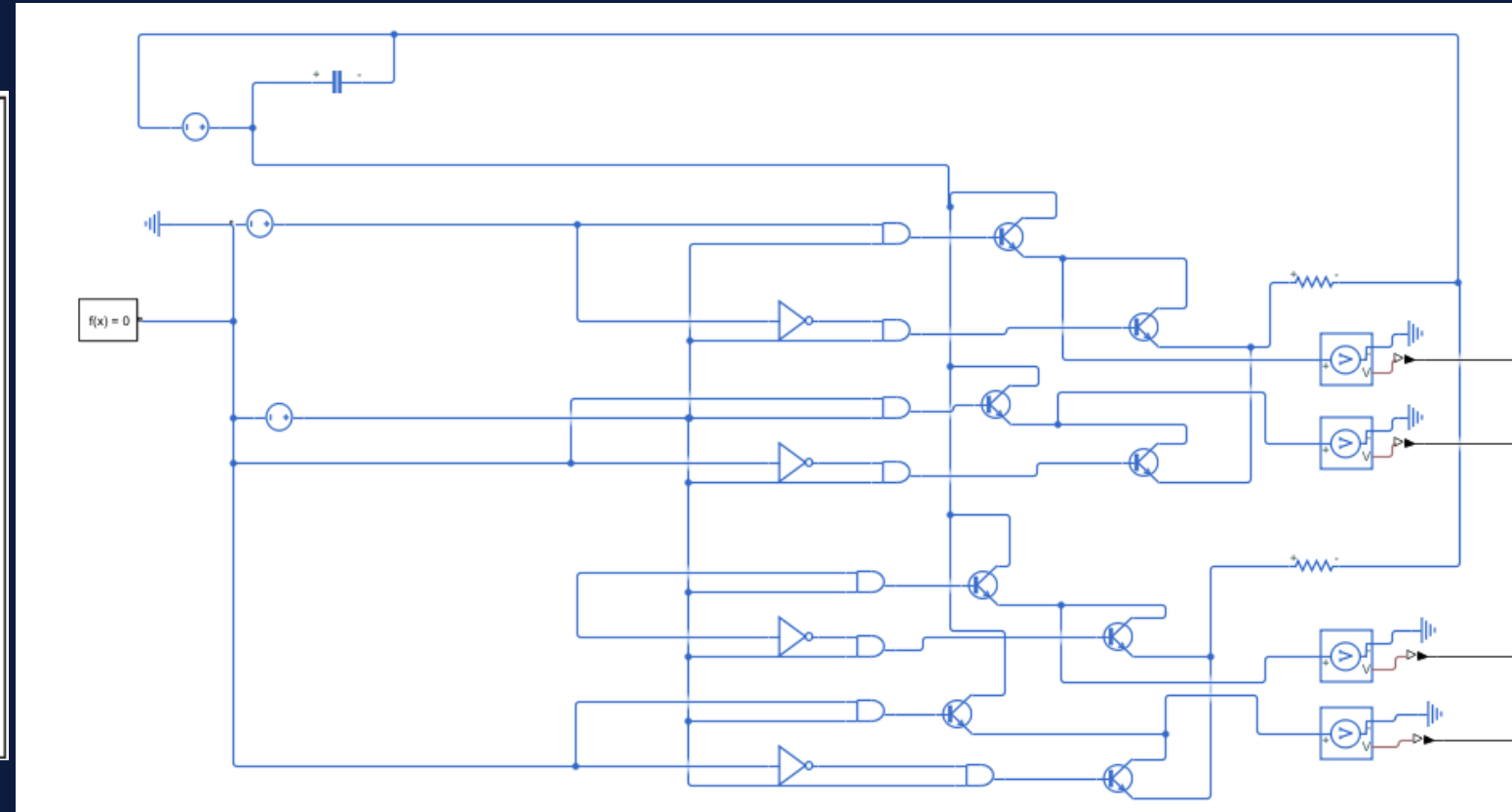
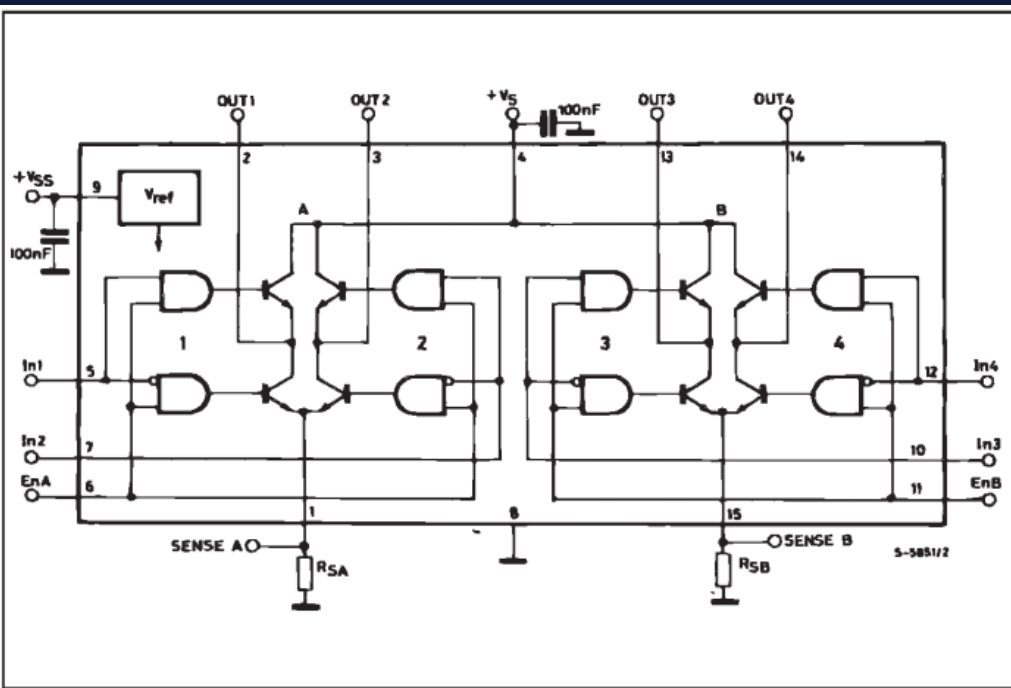
MODEL	VOLTAGE		NO LOAD		AT MAXIMUM EFFICIENCY				STALL	
	OPERATING RANGE	NOMINA V	SPEED r/min	CURRENT A	SPEED r/min	CURRENT A	TORQUE N.m	OUTPUT w	TORQUE N.m	CURRENT A
NP02D-288	3.0 - 12.0	6	21	0.10	19	0.17	0.05 0.47	0.18	0.18 1.8	0.6

Tw = nVI!!!

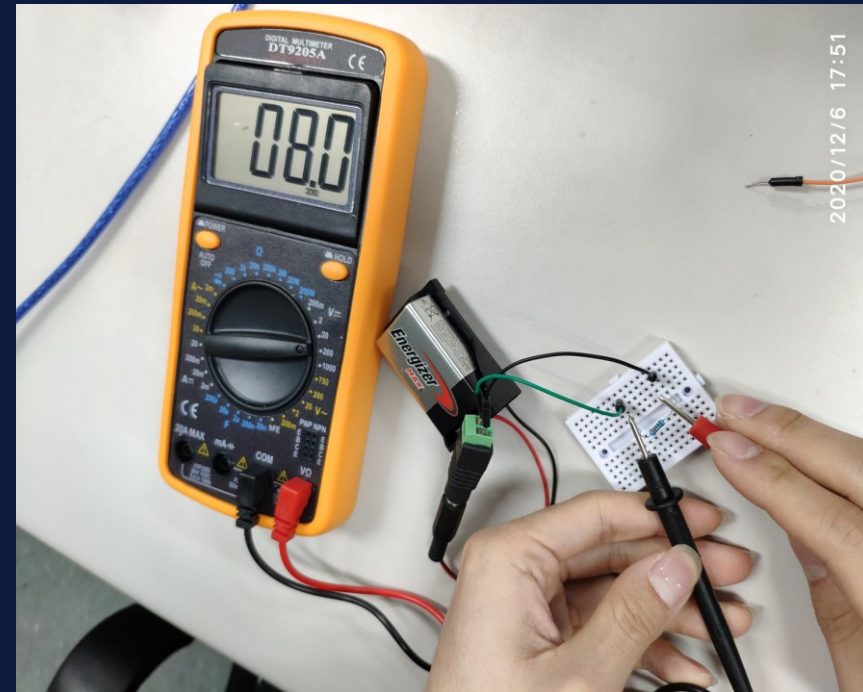


Input Voltage(V)	Output Current(A)
3.378	0.103
3.250	0.142
1.586	0.6

2-2. MATLAB& Simulink-L298n motor driver



2-2. MATLAB&Simulink -Internal Resistance



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

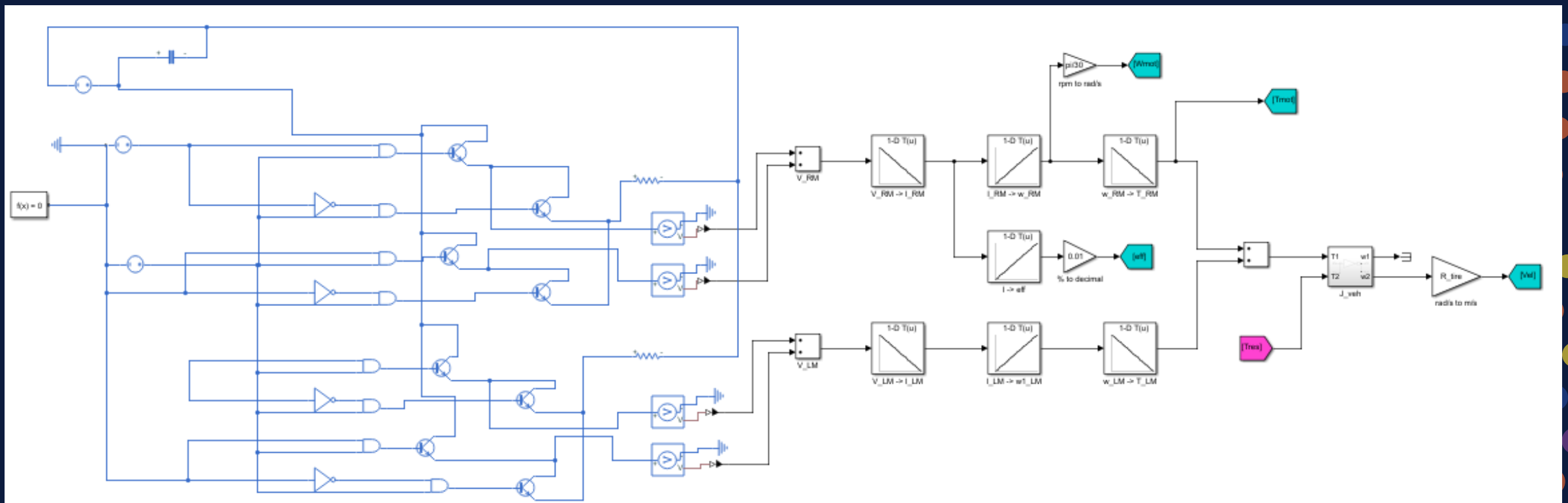
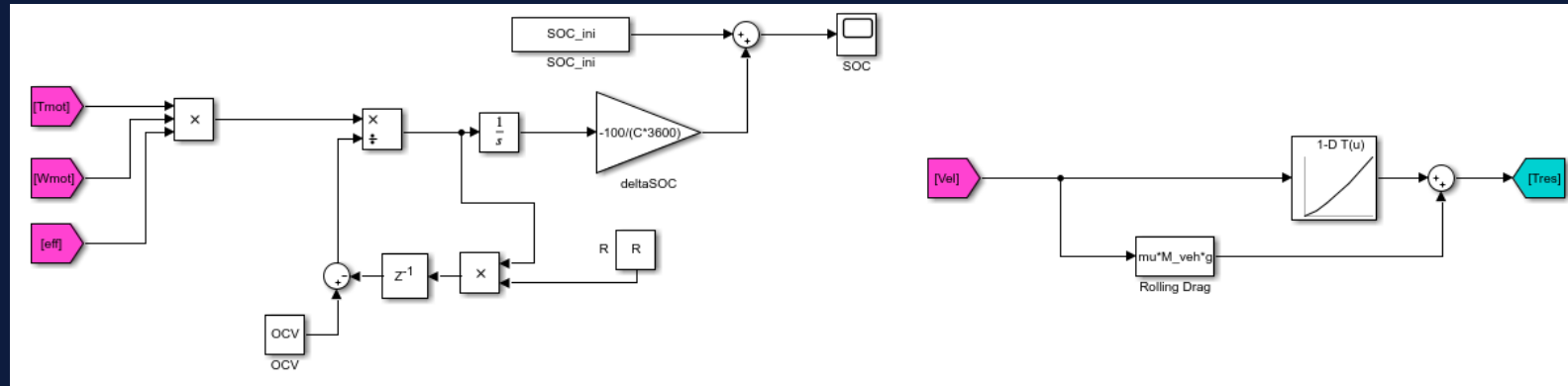
2-2. MATLAB&Simulink -Script

```
1 - clear;
2 - %%Voltage control
3 - V_on = 5;
4 - V_off = 0;
5 - Signal_pwm = 200;
6 - V_pwm = 5*Signal_pwm/255; %V
7 - GND = 0;
8
9 - %%Vehicle
10 - M_veh = 0.744; %kg
11 - mu = 0.01;
12 - g = 9.81;
13
14 - %%Drag Force
15 - Vel_input = [0.1, 0.15, 0.2, 0.3, 0.4];
16 - Drag_output = [1.83e-5, 5.34e-5, 9.45e-5, 2.12e-4, 3.73e-4];
17
18 - %%Battery
19 - SOC_ini = 1;
20 - OCV = 8.6; %V
21 - R = 16.5; %ohm
22 - C = 0.6; %Ah
23
24 - %%Motor
25 - R_tire = 0.0365; %m
```

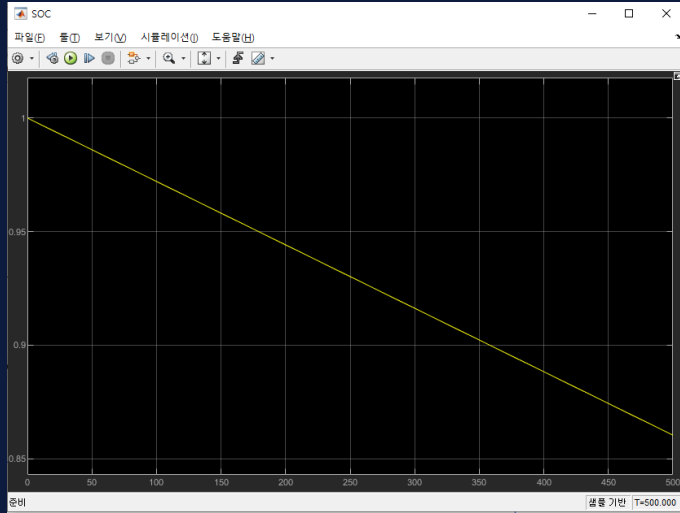
```
27 - l_input = linspace(0.1,0.6,20);
28 - l_output = linspace(0.1,0.6,20);
29 - V_input = linspace(3.378,1.586,20);
30 - w_output = linspace(3.5, 21, 20); %rpm
31 - eff_output = linspace(10,50,20);
32 - w_input = linspace(21,0,20); %rpm
33 - T_output = linspace(0,0.18,20);
34
35 - subplot(2,2,1)
36 - plot(V_input, l_output)
37 - legend('l with respect to V')
38 - xlabel('V'); ylabel('A')
39 - subplot(2,2,2)
40 - plot(l_input, w_output)
41 - legend('w with respect to l')
42 - xlabel('A'); ylabel('RPM')
43 - subplot(2,2,3)
44 - plot(V_input, eff_output)
45 - legend('efficiency with respect to V')
46 - xlabel('V'); ylabel('%')
47 - subplot(2,2,4)
48 - plot(w_input, T_output)
49 - legend('T with respect to w')
50 - 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
l_input	1x20 double
l_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

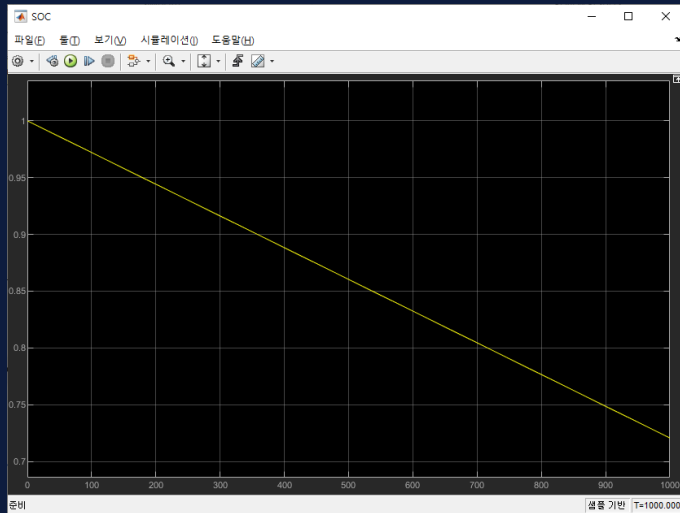
2-2. MATLAB & Simulink - Model



2-2. MATLAB & Simulink –SOC



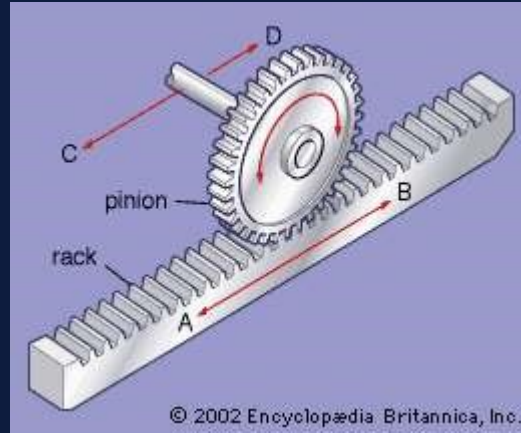
T = 500s



T = 1000s

	T = 500s	T = 1000s
Numerical	$\Delta 0.14$	$\Delta 0.28$
Actual	$\Delta 0.22$	$\Delta 0.42$
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

Added study:

 Time Dependent

Added physics interfaces:

 Solid Mechanics (solid)

2-3. COMSOL - Pushing Force

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

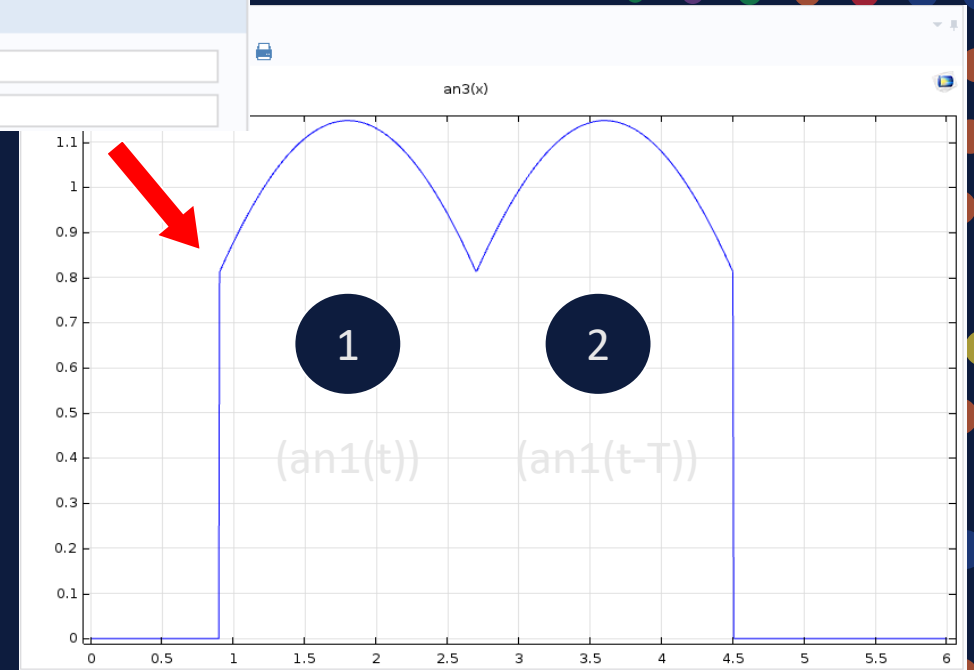
Definition

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

Arguments: x

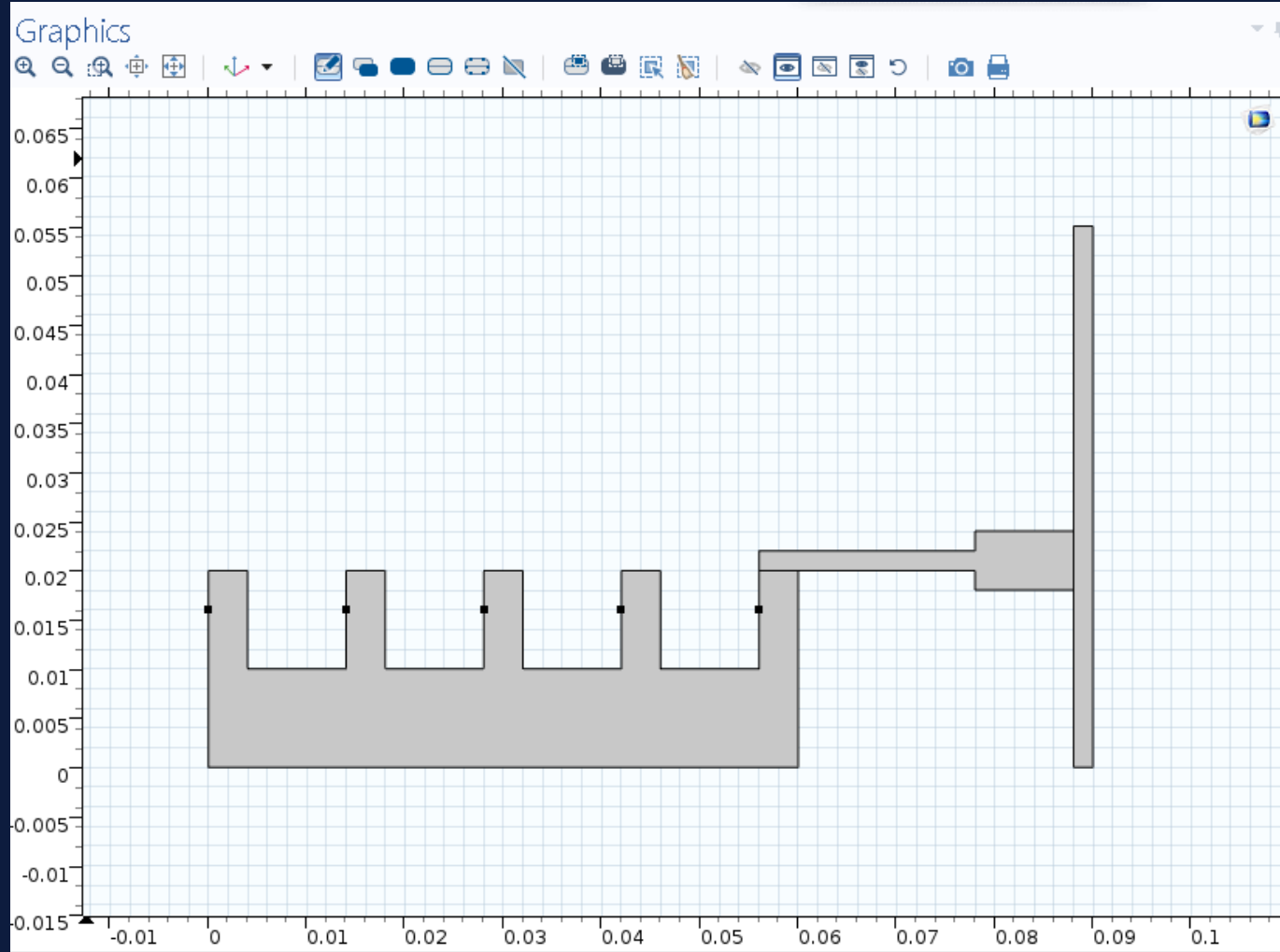
gear3.mph (root)

- Global Definitions
 - Variables
 - Functions
 - Analytic
 - Interpolation
 - Piecewise
 - Gaussian Pulse
 - Ramp
 - Rectangle
 - Step
 - Triangle
 - Waveform
 - Random
 - External
 - Elevation (DEM)
 - Image
 - Switch
 - Load Group
 - Constraint Group
 - Geometry Parts
 - Mesh Parts
 - Group by Type
- Results
 - Derived Values
 - Line Integration 1
 - Point Evaluation 1
 - Point Evaluation 2
 - Line Integration 2
 - Tables
 - Stress (solid)
 - Export
 - Reports



2-3. COMSOL - Pushing Force

- Geometry 1
 - Bézier Polygon 1 (*b1*)
 - Point 1 (*pt1*)
 - Point 2 (*pt2*)
 - Point 3 (*pt3*)
 - Point 4 (*pt4*)
 - Point 5 (*pt5*)
 - Bézier Polygon 2 (*b2*)
 - Rectangle 1 (*r1*)
 - Form Union (*fin*)



2-3. COMSOL - Pushing Force

The image displays the COMSOL Multiphysics interface for a solid mechanics simulation. On the left, the **Solid Mechanics (solid)** node tree is visible, with the following items listed: Linear Elastic Material 1, Free 1, Initial Values 1, Point Load 1, **Roller 1**, Point Load 2, Point Load 3, Point Load 4, Point Load 5, Boundary Load 1, and Mesh 1. The **Roller 1** node is highlighted with a red box. Red lines connect this node to the material property settings and the 2D cross-section of the part.

The material property settings are shown in the center-right, with the following values:

- Thickness:** $d = 0.025$ m
- Young's modulus:** $E = 3275e6$ Pa
- Poisson's ratio:** $\nu = 0.32$
- Density:** $\rho = 1450$ kg/m³

At the bottom, a 2D cross-section of the mechanical part is shown. The vertical axis ranges from -0.005 to 0.02. The part features a base with a central slot and four vertical supports. A blue line is drawn along the bottom surface of the part, indicating the location of the roller support.

2-3. COMSOL - Pushing Force

- Solid Mechanics (solid)
 - Linear Elastic Material 1
 - Free 1
 - Initial Values 1
 - Point Load 1
 - Roller 1
 - Point Load 2
 - Point Load 3
 - Point Load 4
 - Point Load 5
 - Boundary Load 1
 - Mesh 1

F_p User defined

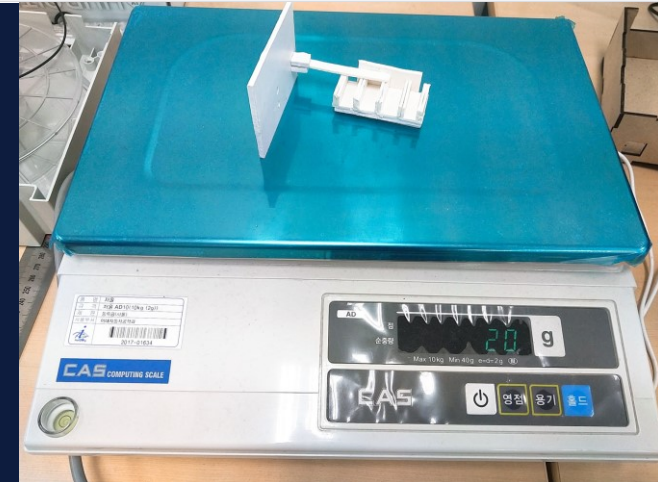
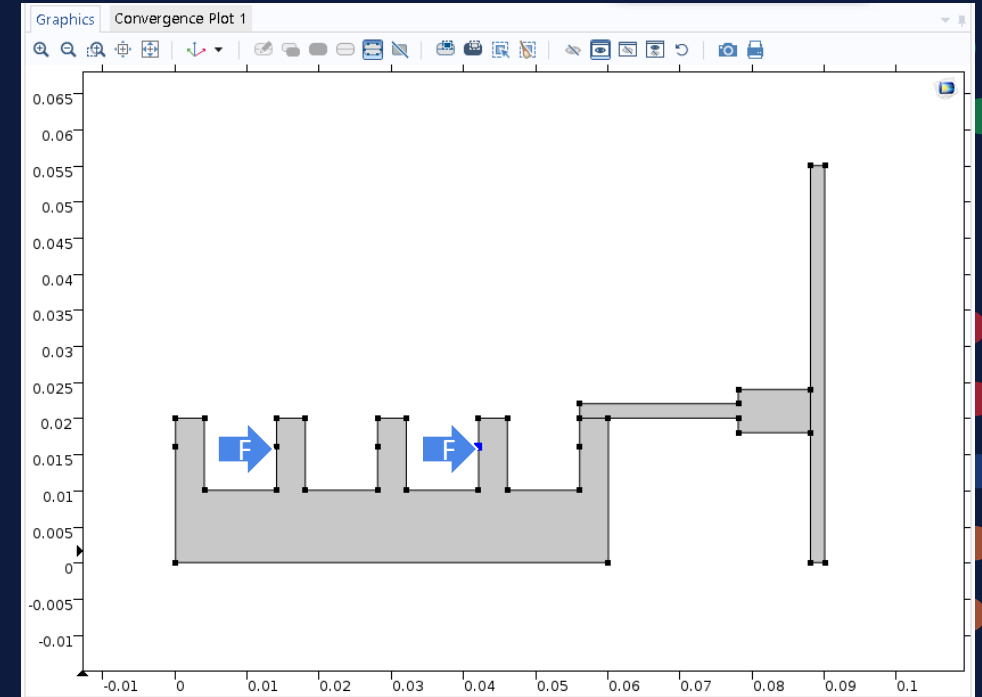
$a n_1(t)[1/s]$	x	N
0	y	

F_p User defined

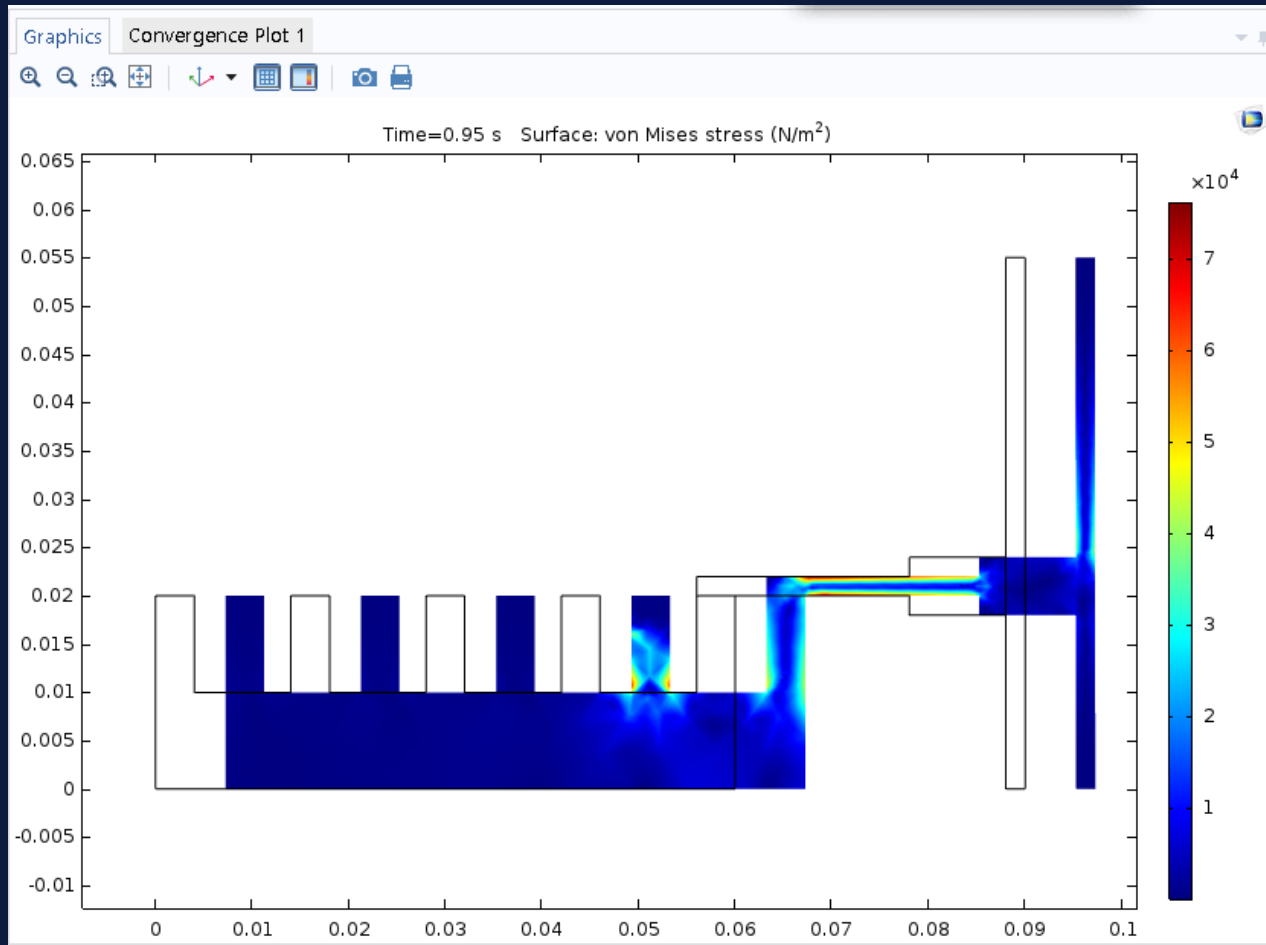
$a n_1((t-T)[1/s])$	x	N
0	y	

Load type: Total force

F_{tot}	$-0.23*0.02*9.81*step((t-T/2)[1/s])$	x	N
	0	y	



2-3. Result & Comparison - Numerical



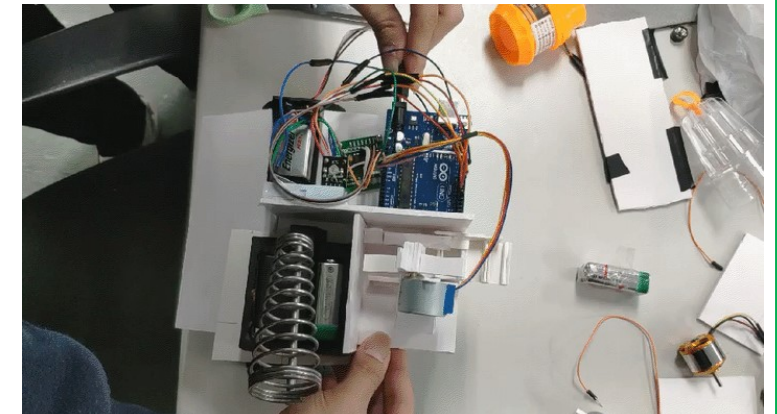
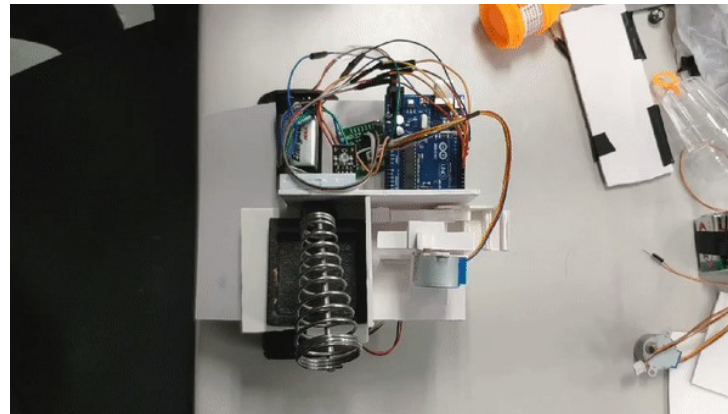
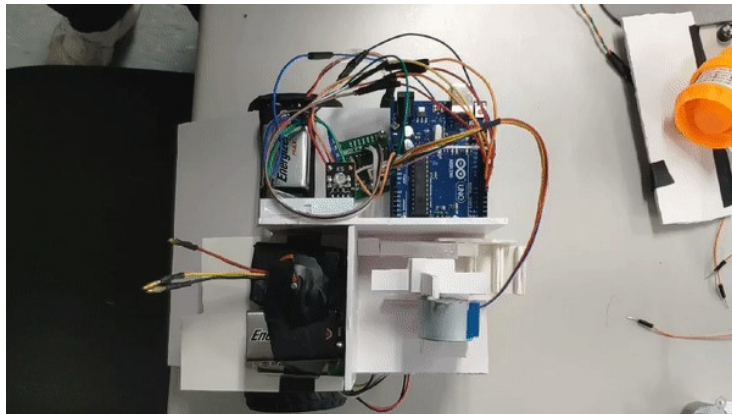
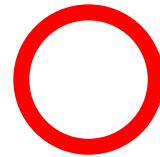
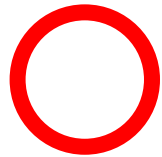
Time (s)	Stress tensor, x component (N/m)
0.90000	0.0000
1.0000	12.551
1.1000	13.751
1.2000	14.390
1.3000	15.052
1.4000	15.653
1.5000	16.109
1.6000	16.421
1.7000	16.618
1.8000	16.683
1.9000	16.619
2.0000	16.424
2.1000	16.107
2.2000	15.650
2.3000	15.115
2.4000	14.392
2.5000	13.670
2.6000	12.734
2.7000	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
 $16[\text{N/m}]$



Max Pushing
Force ($16 \cdot 0.075$)
=
Friction Force
($0.45 \cdot m \cdot 9.81$)
 $m=271\text{g}$

2-3. Result & Comparison - Real



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!**

