MOTOR MOUNTING/POSITIONING LOCATION

Front Wheel – On Top

Function	Weighting	Score	Justification
Comfort for user	5	5	It does not affect the amount of effort required from the user. Their pedaling pace remains the same.
Attachment/Detachment	4	5	Requires the least effort/is accessible. There is no obstacle intrinsic to the TfL bike that would hinder attachment.
Security of Attachment	5	4	There are many features of the TfL bike mechanism could be attached to without disrupting the design of the bike. However, because it is on top of the wheel. Any vertical motion of the wheel would affect the mechanism, so to be secure it would require a damping system.
Balance	5	2	Center of gravity is towards the back wheel of the bike, so any changes to the front wheel will cause difficulties in control.
Design Disruption	2	5	There is a clear place where the mechanism could go; the position of the mechanism works in synergy with the existing design, rather than requiring modifications.

Front Wheel – On Side

Function	Weighting	Score	Justification
Comfort for user	5	5	It does not affect the amount of effort required from the user. Their pedaling pace remains the same.
Attachment/Detachment	4	4	Would require older individuals to bend down to attach, would not be as accesible.
Security of Attachment	5	4	Forks allow for secure attachment to the wheels. Side location also means system is less susceptible to vibrations and impact, so is less likely to slip or get damaged.
Balance	5	3	Same issues with center of gravity changes in front wheel, but because a side attachment would be lower than a top attachment, it has a lower center of gravity which is more beneficial for balance.
Design Disruption	2	4	Can integrate with exisitng features well and shouldn't be protrude out too much

Back Wheel – On Top

Function	Weighting	Score	Justification
Comfort for user	5	5	It does not affect the amount of effort required from the user. Their pedaling pace remains the same.
Attachment/Detachment	4	4	Would require older individuals to bend down to attach, would not be as accessible.
Security of Attachment	5	4	Forks allow for secure attachment to the wheels. Side location also means system is less susceptible to vibrations and impact, so is less likely to slip or get damaged.
Balance	5	3	Side attachment would be lower than a top attachment, it has a lower center of gravity which is more beneficial for balance.
Design Disruption	2	4	Can integrate with existing features well and shouldn't be protrude out too much.

Back Wheel – On Side

Function	Weighting	Score	Justification
Comfort for user	5	5	It does not affect the amount of effort required from the user. Their pedaling pace remains the same.
Attachment/Detachment	4	3	Would require older individuals to bend down to attach, would not be as accessible.
Security of Attachment	5	3	Forks allow for secure attachment to the wheels. Side location also means system is less susceptible to vibrations and impact, so is less likely to slip or get damaged. However, back wheel is exposed to higher forces because it is the location where somebody sits so would be less secure.
Balance	5	4	Side has lower center of gravity. Back wheel is beneficial as there is no change to natural center of gravity.
Design Disruption	2	3	More access than back wheel on top but mudguard still provides great difficulty with attachment and design.

Pedal Attachment

Function	Weighting	Score	Justification
Comfort for user	5	1	Because it directly drives the big chain ring, it would require the user to pedal faster, exerting more effort.
Attachment/Detachment	4	1	There is a chain guard on the TfL bike, so this would have to be removed to install. As well as this, it would have to be ensured that the sprocket meshes with the chain/large chain ring. This would require experience in installation.
Security of Attachment	5	4	As it would need to be secured to the sprocket, it will be very secure, but the chain guard may be disruptive.
Balance	5	2	Could be unstable as design leans to one side. However, the system would be unlikely to slip.
Design Disruption	2	2	Fitting with the chain guard space is difficult with limited space and access.

DRIVE METHOD

Friction Drive

Function	Weighting	Score	Justification
Wear	2	2	Design is in direct contact with wheel, friction would cause wear on either tire or rim of bike.
Simplicity of Design	4	5	There are only three real components to consider, and the mechanism is intuitive in design.
Attachment/Detachment	5	5	Attaches externally, does not require extensive fitting with design.

Direct Axle Drive

Function	Weighting	Score	Justification
Wear	2	4	No real wear on components, may wear hub but nothing more than any moving hub.
Simplicity of Design	4	4	This is just a motor that moves (the motor is the hub), there little complexity required for design.
Attachment/Detachment	5	2	Bike has to be disassembled to install, would be very difficult for inexperienced individuals to attach and would require tools to do so.

Geared Hub Motor

Function	Weighting	Score	Justification
Wear	2	4	No real wear on components, may wear hub but nothing more than any moving hub.
Simplicity of Design	4	4	This is just a motor that moves (the motor is the hub), there little complexity required for design.
Attachment/Detachment	5	2	Bike has to be disassembled to install, would be very difficult for inexperienced individuals to attach and would require tools to do so.

Direct Sprocket Drive

Function	Weighting	Score	Justification
Wear	2	4	Sprocket is designed to mesh with chain, there would be no more wear than an average rigid drive transmission.
Simplicity of Design	4	1	Meshing mechanism with the chain drive would be very difficult.
Attachment/Detachment	5	1	Must mesh with the existing sprockets and so is harder to attach.

Product Design Specification

Product title – Portable E-bike drive

Project Leader – Punit Jivan

Project Team - 21

Name	Function
Punit Jivan	Project Manager
Tarun Bhaskaran	Submission Specialist, CAD & Design Head
Annamaria McHugh	Secretary, Reporting Head
Mohit Agarwalla	Communications Head, Documentation Head

Version	Details of changes	date
1.0	Initial release.	14/2/2022

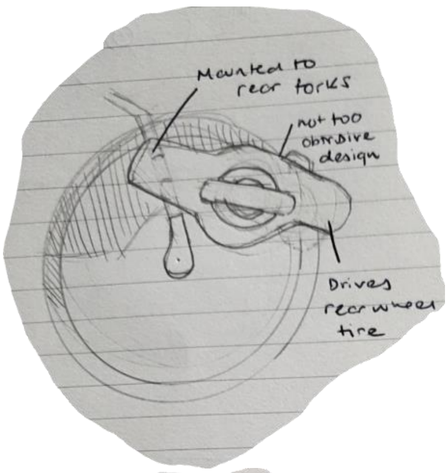
Element	Statement or criteria	verification by
Customer		
Needs	*Product to enable public bike to become battery assisted. Should be lightweight, easy to attach, portable, and have adequate range and operating life.*	
Competition	*Several products exist already, however most of these are for long-term usage, requiring time-intensive installation to turn a regular bike into an electrical bike. All devices in the market are for personal bike usage, not designed for public bikes. There are a range of devices that use either a friction drive or direct axle transmission. They are within the price range of* ***£500- £1,000***	
Aesthetics	*Should not look out of place on a TfL bike: should fit in with the overall design and not protrude excessively.*	*Focus Groups to evaluate the aesthetic synergy of design by rating out of 10 when presented in a group with other bikes*
Operation		
Performance	*With attachment, bike should produce speeds of* ***15.5 mph*** *while user does no pedalling. Should have a minimum range of* ***10 miles.*** *The final torque on the wheel should be between* ***1.25-1.5 Nm****.* *Final Power:* ***31.21W*** *Battery life:* ***30 minutes.***	*Calculation & Testing for speed and battery life*
Environment	*Outdoor operation must be suitable for all weather use – water resistance should be emphasized with electrical components in mind.*	*Testing in different weather conditions*
Size	*Must be portable, should be able to fit in a standard bag. Should not exceed* ***30 x 30 x 20 cm*** *so that it can fit into a standard bag.*	*Design Review & Measure Prototype with ruler*
Weight	*Product should be 'Lightweight' to facilitate portability and not hinder the user. Must be between* ***2.5 - 6 kg****.*	*Place on scales and find mass*
Ergonomics	*Portability should be emphasized, should fit into a backpack. Should have 'soft touch' materials on grip locations i.e., soft thermoplastics. Should make use of colour for parts of design that require human*	*Design Review*

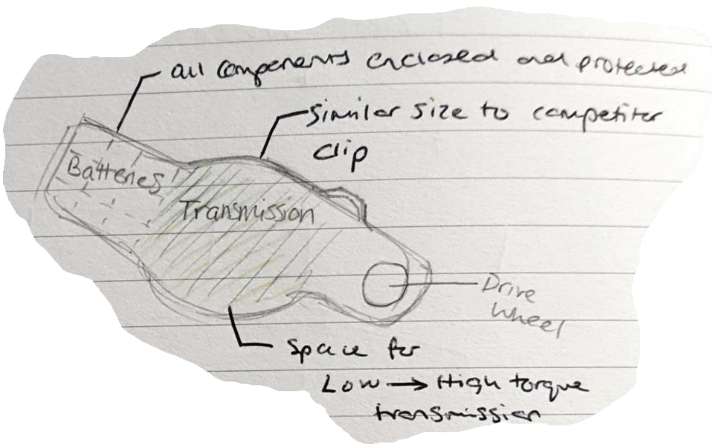
	interaction and action (start button should be distinct colour to draw attention).	
Life		
Product Life	*Should last atleast 5 years with regular servicing*	*Calculation/ Simulation*
Service Life	*Should be able to withstand 1,000 miles of use before maintenance is required.* *Should be able to last 300 charge cycles before replacement*	*Calculation and Design Review*
Maintenance	*Batteries should be easily replaceable by user. Motor and moving components easy to replace and maintain by technician.*	*Design Review*
Producer		
Quantity	*Initial production run of 2500 products*	*Calculation*
Production Cost	*Less than £500 per unit @ 2500 units*	*Calculation*
Regulatory		
Safety Standards	*Compliance with UK EAPC government guidelines.*	*Design Review*
Product Regulations	*UK EAPC Product guidelines to be adhered to:* *Motor power cannot exceed 250 W* *Bike Cannot be propelled over 15.5 mph without pedalling.*	*Design Review and Prototype Testing*
End of Life disposal	*Waste Electrical and Electronic Equipment (WEEE) standards*	*Design Review*

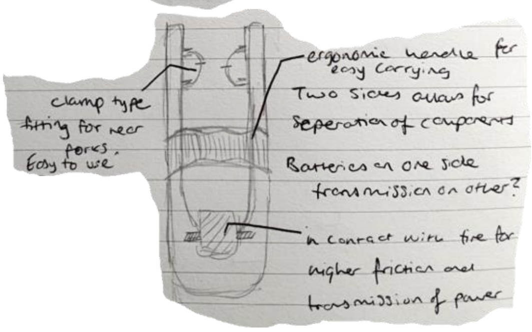
	Monday							
Tasks	9am - 10am	10am-11am	11am -12pm	12pm-1pm	1pm - 2pm	2pm - 3pm	3pm - 4pm	4pm - 5pm
Read Brief								
Meet with Tom								
PDS								
Lunch								
Concept Design								
Final checks								

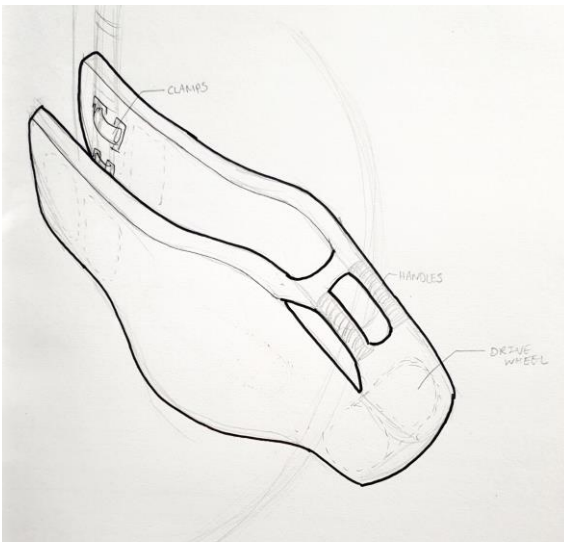
	Tuesday							
Tasks	9am - 10am	10am-11am	11am -12pm	12pm-1pm	1pm - 2pm	2pm - 3pm	3pm - 4pm	4pm - 5pm
Breakfast								
Meet with Tom								
Motor Selection								
Transmission								
Lunch								
Material Selection								
Sketches + Dimensions								

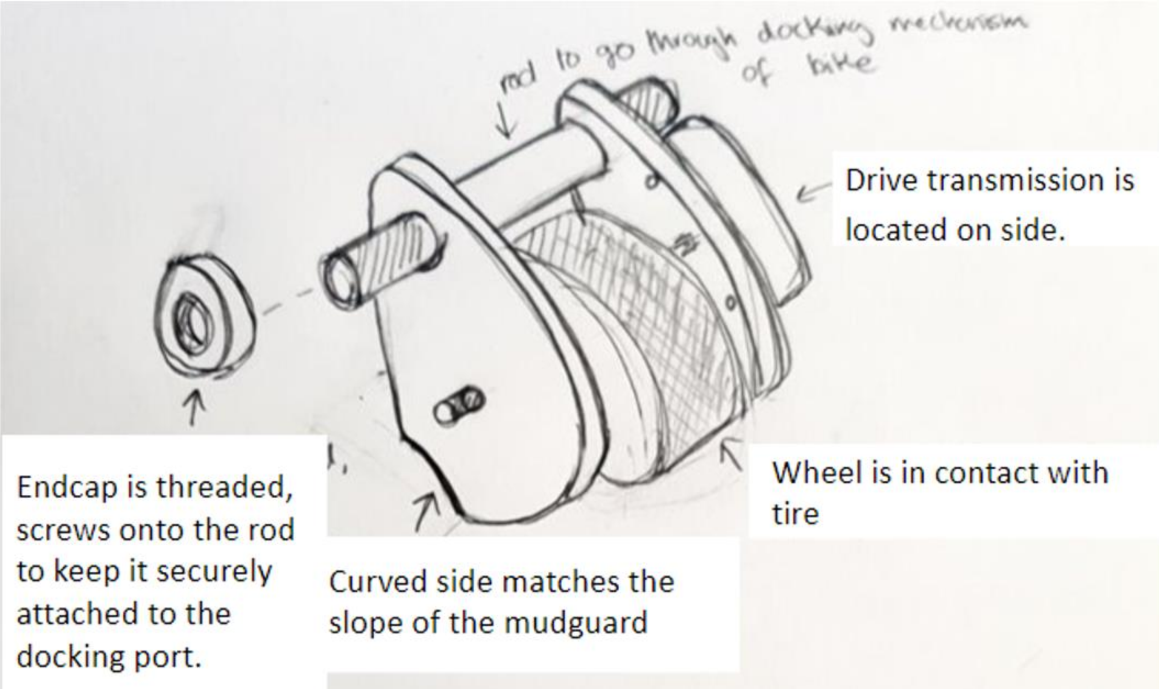
ADD PDS

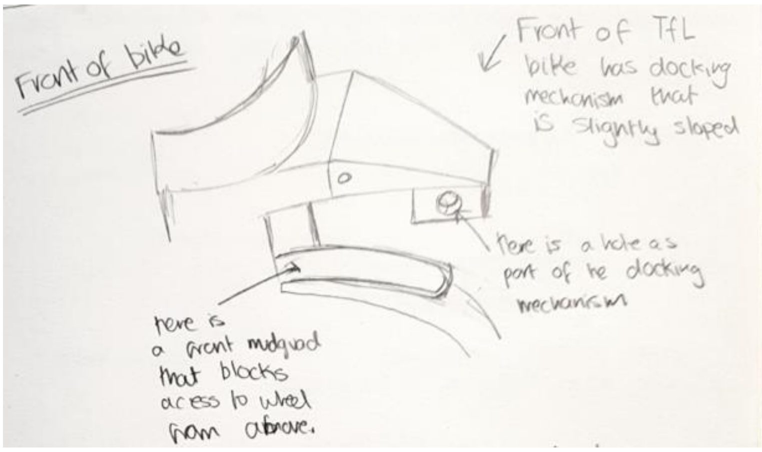


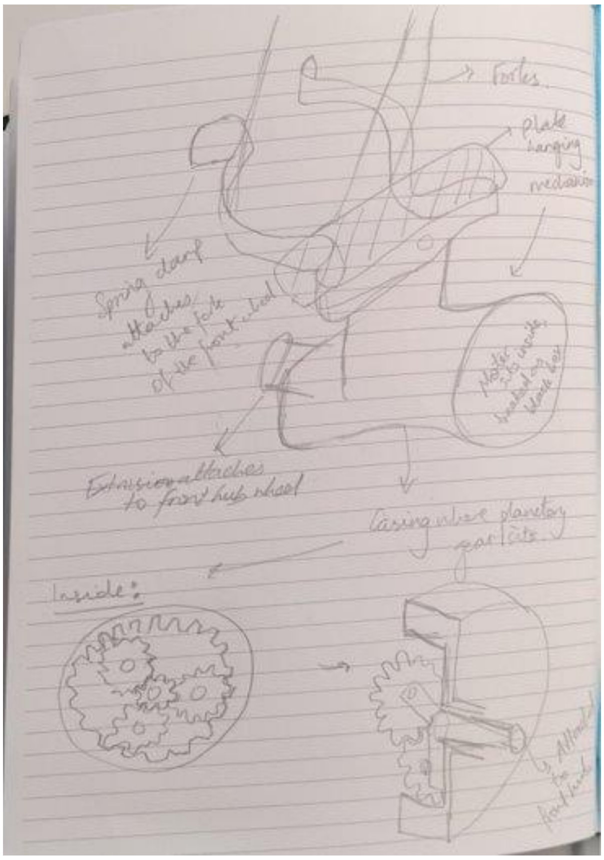


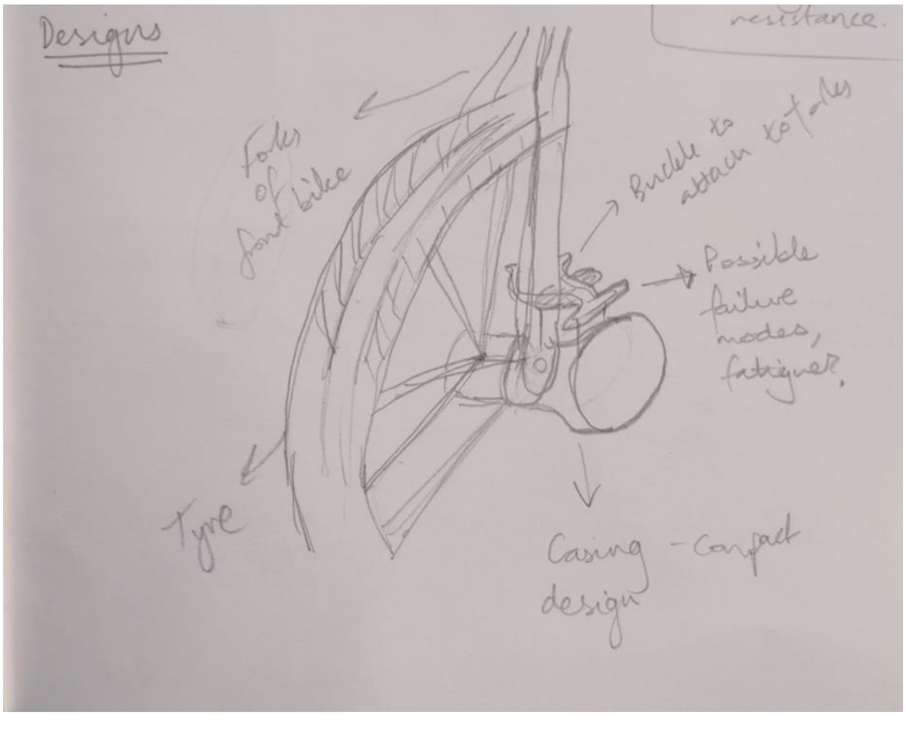





rod to go through docking mechanism of bike
Drive transmission is located on side.
Endcap is threaded, screws onto the rod to keep it securely attached to the docking port.
Curved side matches the slope of the mudguard
Wheel is in contact with tire

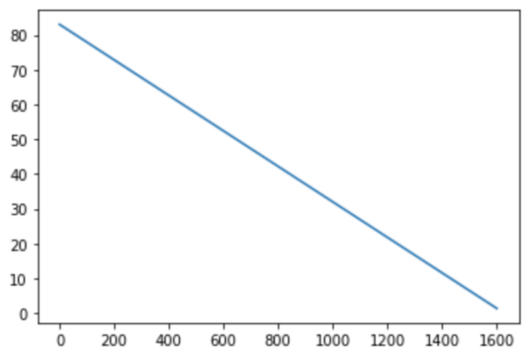

Front of bike
Front of TfL bike has docking mechanism that is slightly sloped
here is a hole as part of he docking mechanism
here is a front mudguad that blocks acess to wheel from above.


Forks.
Plate hanging mechanism
Spring damp attaches to the fork of the front wheel
Motor sits inside sealed off black box
Extension attaches to front hub wheel
Casing where planetary gear sits.
Inside:


Designs
resistance.
Forks of front bike
Buckle to attach to forks
Possible failure modes, fatigue?
Tyre
Casing - compact design

```python
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
nom_v = 12
Noloadspeed = 1850
noloadcurrent = 0.005
stalltorque = 5.4e-3
stallcurrent = 0.1

frictionballspeed = 276.76
tirepower = 132.64
tireeff = 0.9
frictionballpower = tirepower/tireeff
frictionballtorque = 0.487

noloadspeed = Noloadspeed* 2*np.pi/60
speed = np.arange(0,noloadspeed,2)
grad1 = -stalltorque/noloadspeed
grad2 = -(stallcurrent-noloadcurrent)/noloadspeed
torque = np.zeros(len(speed))
current = np.zeros(len(speed))
efficiency = np.zeros(len(speed))
electricpower = np.zeros(len(speed))
for i in range(len(speed)):
    torque[i] = grad1*speed[i]+stalltorque
    current[i] = grad2*speed[i]+stallcurrent
```

```python
    electricpower[i] = nom_v * current[i]

power = (speed * torque)/0.95
efficiency = power/electricpower

maxindex = np.argmax(power)
maxpowerspeed = speed[maxindex]
maxpowertorque = torque[maxindex]
maxpowerpower = power[maxindex]
print(maxindex)

print(speed[maxindex])

speedratio = maxpowerspeed/frictionballspeed
torque_actual = frictionballtorque/speedratio

if maxpowerpower>frictionballpower:
    print("Power works")

if torque_actual>maxpowertorque:
    print("Torque works")
```



80
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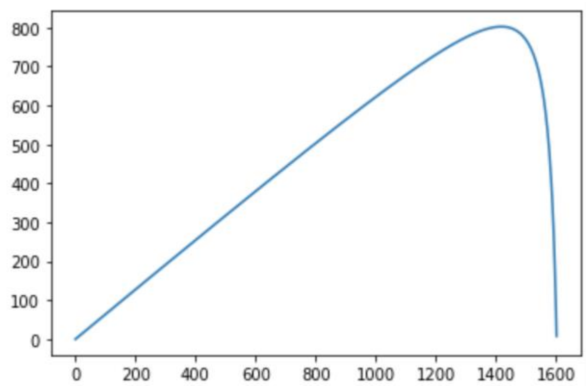
0 200 400 600 800 1000 1200 1400 1600



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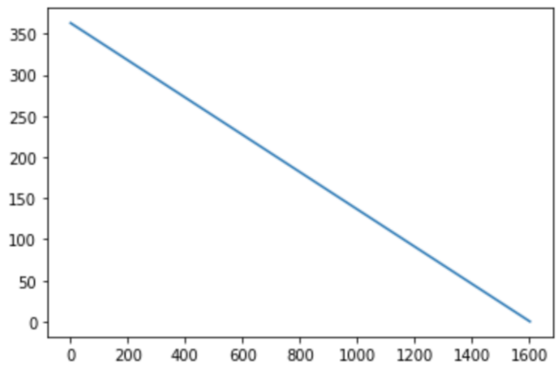

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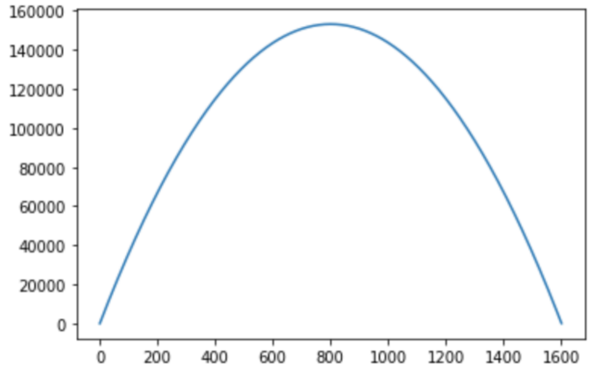

160000
140000
120000
100000
80000
60000
40000
20000
0
0 200 400 600 800 1000 1200 1400 1600

```python
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
# Constants pre-calculated
desired_speed = 276.76 # desired ouput speed
desired_power = 132.64 / 0.9 # Desired output power
desired_torque = 0.487 # Desired output torque

df = pd.read_excel('Mabuchi_motor.xlsx') # Read data as a panda

number_of_rows = len(df.index)
# iterate through each motor
for i in range(1,number_of_rows):
    nom_v = df['Nom_voltage'][i]
    no_load_speed_rpm = df['No load speed'][i]
    no_load_current = df['No load current'][i]
    stall_torque = df['Stall torque'][i] * 10**(-3)
    stall_current = df['Stall current'][i]

    no_load_speed = no_load_speed_rpm* 2*np.pi/60
    # Calculate gradients
    grad_torque = - stall_torque / no_load_speed
    grad_current = (no_load_current - stall_current) / no_load_speed

    # Create arrays for variables
    speed = np.arange(0,no_load_speed,2)
    torque = np.zeros(len(speed))
    current = np.zeros(len(speed))
    electric_power = np.zeros(len(speed))


    for j in range(len(speed)):
        torque[j] = grad_torque * speed[j] + stall_torque
        current[j] = grad_current * speed[j] + stall_current
        electric_power[j] = nom_v * current[j]



    mechanical_power = speed * torque / 0.95 # Assume 95% efficiency due to losses
    efficiency = mechanical_power/electric_power

    # Find index of max power to calculate variables at max power
    index_max_power = np.argmax(mechanical_power)
    max_power = mechanical_power[index_max_power]
    efficiency_max_power = efficiency[index_max_power]
    torque_max_power = torque[index_max_power]
    speed_max_power = speed[index_max_power]
    speed_max_power_rpm = speed_max_power * 60 / (2*np.pi)
    current_max_power = current[index_max_power]

    if (torque_max_power > desired_torque) and (max_power > desired_power):
        print(df['Model'][i]," ", speed_max_power, " ", no_load_speed, efficiency_max_power, current_max_power)
```

```
RS-775VC-8016    942.0    1884.955592153876 0.5287889584849951 51.12479021602368
RS-775WC-8514    1022.0    2042.0352248333656 0.5476466270687314 66.28875818701096
RZ-8BAWA-AWG19.5x9    1058.0    2115.3390534171276 0.4757068238905131 60.282596300764865
RZ-735VA-9517    1068.0    2136.2830044410593 0.49752762337071316 79.41014759755149
RS-775WC-9013    1100.0    2199.114857512855 0.5245775232686968 79.36916854329657
RT-8B7WA-A19    1168.0    2335.2505391684126 0.539877545564973 94.92109991122902
```