Appendix A - Power Calculations for 2005 Ford Mustang

Assumptions:

Initial Velocity = 26.822 m/s (60 mph)
Final Velocity = 0 m/s
Time for Braking = 0.1 min (6 sec)
Time Between Braking = 1.4 min (84 sec)
Mass of Vehicle = 1554 kg (3425 lbs)
Weight Distribution = 57F/43R
Wheelbase = 2720 mm (107.08 in.)
Center of Gravity = 527.56 mm (20.77 in. Based on data from 2003 Model)
Rotor Diameter = 316 mm

Variable Declaration:

$vel_i := 26.822 \cdot \frac{m}{sec}$	Initial Velocity of Vehicle
$vel_f := 0 \cdot \frac{m}{sec}$	Final Velocity of Vehicle
$n_{brake} := 10$	Number of Braking Time Steps
$n_{model} := 2000$	Number of Model Time Steps
$t_{brake} := 0.1 \cdot min$	Time for Braking
$time := 0 \cdot min, \frac{t_{brake}}{n_{brake}} .. t_{brake}$	Time Range for Braking
$mass_v := 1554 \cdot kg$	Mass of Vehicle
$dia_{rotor} := 316 \cdot mm$	Diameter of Rotor
$w_F := 0.57$	Weight Fraction of Front of Vehicle
$w_R := 0.43$	Weight Fraction of Rear of Vehicle
$L := 2720 \cdot mm$	Wheelbase
$CG := 527.56 \cdot mm$	Vertical Center of Gravity
$k := 1$	Unitless constant, normally calculated based on rotor moment of inertia, wheel radius, and mass of vehicle. It is assumed to be one in this case.

Energy Generated During Braking:

$$E_b := \frac{k \cdot mass_v \cdot vel_i^{\,2}}{2}$$

$E_b = 558989.1\ J$

Deceleration During Braking:

$$a := \frac{vel_i}{t_{brake}}$$

$a = 4.5\ \frac{m}{s^2}$

Power Generated During Braking:

$$P_{total}(time) := k \cdot mass_v \cdot a \cdot (vel_i - a \cdot time)$$

time =		$P_{total}(time)$ =	
0	min	186.3	kW
0.01		167.7	
0.02		149.1	
0.03		130.4	
0.04		111.8	
0.05		93.2	
0.06		74.5	
0.07		55.9	
0.08		37.3	
0.09		18.6	
0.1		0	

Brake Force Distribution:

$mass_F := w_F \cdot mass_v$ $mass_F = 885.8\,kg$ Mass of Front of Vehicle

$mass_R := w_R \cdot mass_v$ $mass_R = 668.2\,kg$ Mass of Rear of Vehicle

$\psi := \frac{mass_R}{mass_v}$ $\psi = 0.4$

$X := \frac{CG}{L}$ $X = 0.2$

$accel_{ratio} := \frac{a}{g}$ $accel_{ratio} = 0.5$

$F_{xFopt} := \left(1 - \psi + X \cdot accel_{ratio}\right) \cdot a \cdot mass_v$ $F_{xFopt} = 4573.9\,N$ Force on Front Brakes

$F_{xRopt} := \left(\psi - X \cdot accel_{ratio}\right) \cdot a \cdot mass_v$ $F_{xRopt} = 2373\,N$ Force on Rear Brakes

$Front_{ratio} := \frac{F_{xFopt}}{F_{xFopt} + F_{xRopt}}$

$Front_{ratio} = 65.8\,\%$ Percentage of Power to the Front Brakes

Power Split Calculations:

$P_{Front}(time) := P_{total}(time) \cdot Front_{ratio}$ Power to Front Brakes

$P_{RightFront}(time) := P_{Front}(time) \cdot 0.5$ Power to Right Front Brake

$Area_{PadContact} := 7112 \cdot mm^2$ Area of Contact Face on Pad

$Area_{RotorContact} := 29079 \cdot mm^2$ Area of Contact Face on Rotor

$Pad_{CRatio} := \frac{Area_{PadContact}}{Area_{PadContact} + Area_{RotorContact}}$

$Pad_{CRatio} = 19.7\,\%$ Percentage of Area covered by Pad Contact

$P_{PadContact}(time) := 0.5 \cdot \left(P_{RightFront}(time) \cdot Pad_{CRatio}\right)$ Power applied to Pad Contact. Divided by two because of Inboard/Outboard Sides

$P_{RotorContact}(time) := P_{RightFront}(time) \cdot \left(1 - Pad_{CRatio}\right)$ Power applied to Rotor Contact.

$P_{PadContact}(time)$ =

W
6027.156
5424.441
4821.725
4219.01
3616.294
3013.578
2410.863
1808.147
1205.431
602.716
0

$P_{RotorContact}(time)$ =

W
49286.75
44358.075
39429.4
34500.725
29572.05
24643.375
19714.7
14786.025
9857.35
4928.675
0

$$P_{RotorSum} := \sum_{time} P_{RotorContact}(time)$$

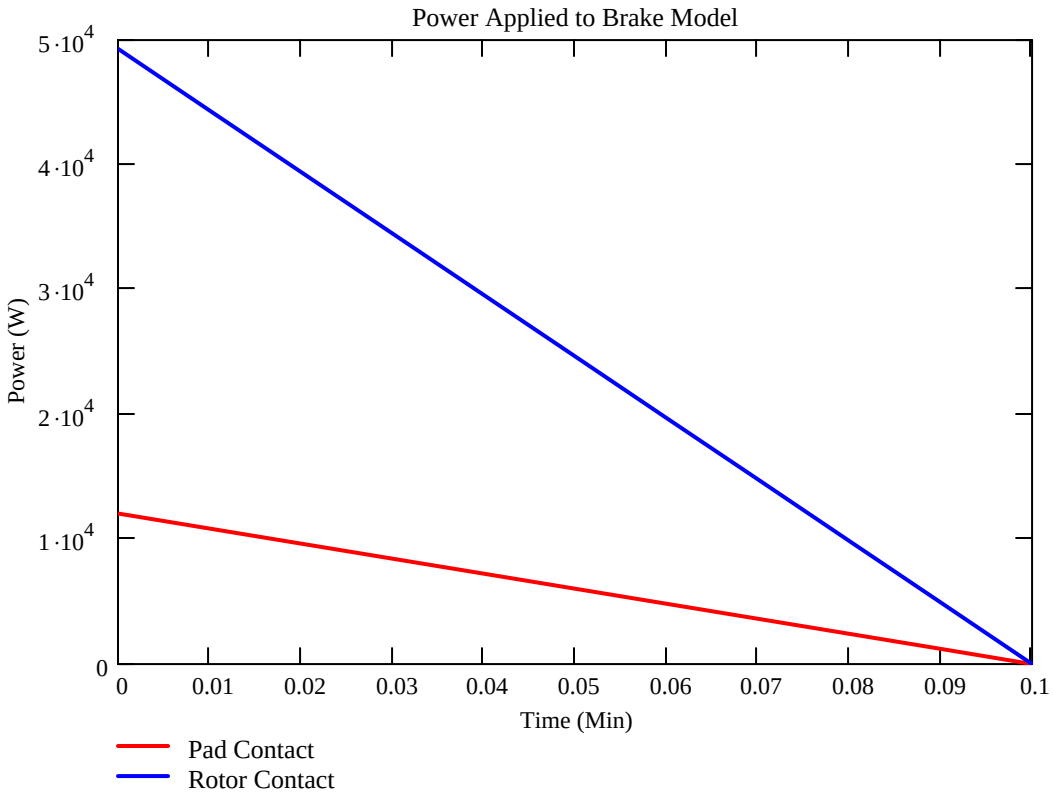
$$\frac{P_{RotorSum}}{n_{brake}} = 27107.7\ W$$

Constant Power on Rotor Contact

$$P_{PadSum} := \sum_{time} P_{PadContact}(time)$$

$$\frac{P_{PadSum}}{n_{brake}} = 3314.9\ W$$

Constant Power on Pad Contact



Velocity Curve Deceleration:

$$vel := vel_i, vel_i - \frac{vel_i}{n_{brake}} .. 0 \cdot \frac{m}{s}$$

vel =

26.8	m/s
24.1	
21.5	
18.8	
16.1	
13.4	
10.7	
8	
5.4	
2.7	
0	

Convection Curve Deceleration:

$$conv := 50 \cdot \frac{W}{m^2 \cdot K}, \left(50 - \frac{50}{n_{brake}}\right) \cdot \frac{W}{m^2 \cdot K} .. 5 \cdot \frac{W}{m^2 \cdot K}$$

conv =

50	W/(m²·K)
45	
40	
35	
30	
25	
20	
15	
10	
5	

Velocity Curve Acceleration:

$$vel := 0 \cdot \frac{m}{s}, 0 + \frac{vel_i}{n_{brake}} .. vel_i$$

vel =

0	m/s
2.7	
5.4	
8	
10.7	
13.4	
16.1	
18.8	
21.5	
24.1	
26.8	

Convection Curve Acceleration:

$$conv := 5 \cdot \frac{W}{m^2 \cdot K}, \left(5 + \frac{50}{n_{brake}}\right) \cdot \frac{W}{m^2 \cdot K} .. 50 \cdot \frac{W}{m^2 \cdot K}$$

conv =

5	W/(m²·K)
10	
15	
20	
25	
30	
35	
40	
45	
50	

Model Time:

$t_{model} := 20 \cdot min$

$time_{model} := 0 \cdot min, \frac{t_{model}}{n_{model}} .. t_{model}$

$time_{model} =$ min

0
0
0
0
0
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.2

Geometry Calculations:

$D_{CI} := 7.77 \cdot \frac{gm}{cm^3}$ $D_{pad} := 2.595 \cdot \frac{gm}{cm^3}$

$D_{Al} := 2.77 \cdot \frac{gm}{cm^3}$

$V_{rotor} := 1714739 \cdot mm^3$ $SA_{rotor} := 326706 \cdot mm^2$

$V_{pad} := 117175 \cdot mm^3$ $SA_{pad} := 24630 \cdot mm^2$

$V_{cal} := 969042 \cdot mm^3$ $SA_{cal} := 148944 \cdot mm^2$

$mass_{rotor} := D_{CI} \cdot V_{rotor}$ $mass_{rotor} = 13.3\,kg$

$mass_{pad} := D_{pad} \cdot V_{pad}$ $mass_{pad} = 0.3\,kg$

$mass_{cal} := D_{Al} \cdot V_{cal}$ $mass_{cal} = 2.7\,kg$

$ratio_{rotor} := \frac{V_{rotor}}{SA_{rotor}}$ $ratio_{rotor} = 5.2\,mm$

$ratio_{pad} := \frac{V_{pad}}{SA_{pad}}$ $ratio_{pad} = 4.8\,mm$

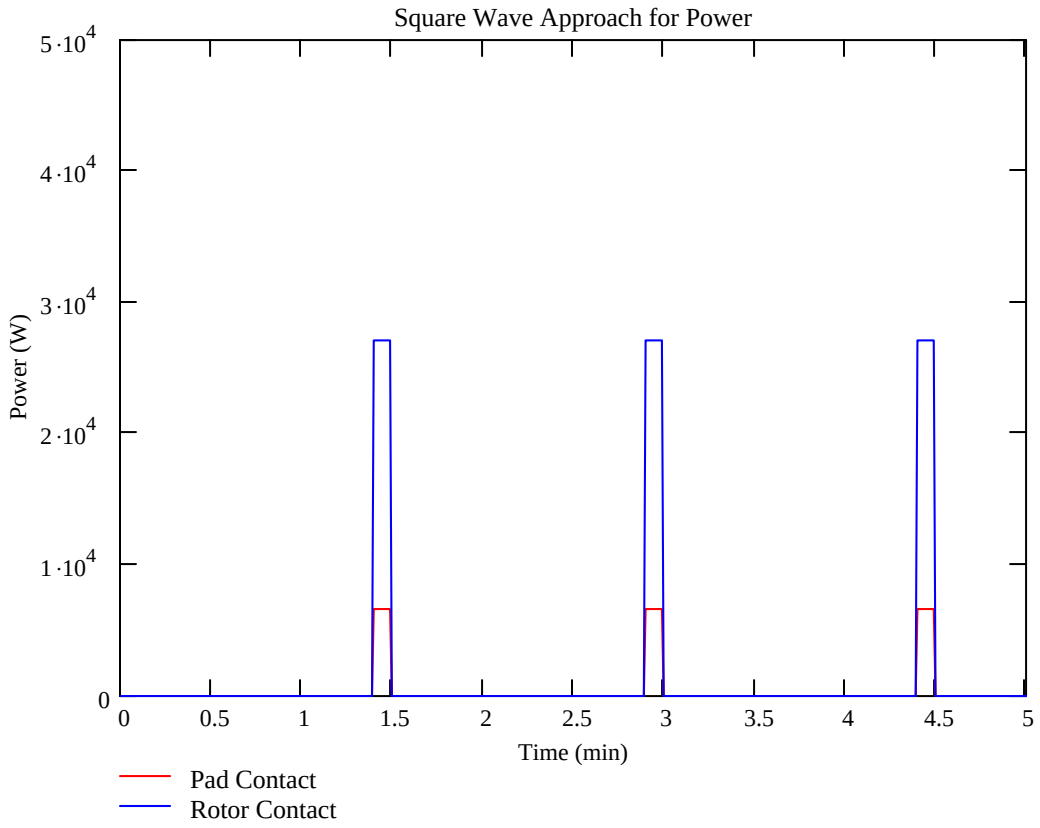
$ratio_{cal} := \frac{V_{cal}}{SA_{cal}}$ $ratio_{cal} = 6.5\,mm$

$\begin{pmatrix} time_{pad} \\ pad_{power1} \end{pmatrix} :=$

Time (Min)	Power (W)					
0.000	0					
0.010	0					
0.020	0					
0.030	0					
0.040	0					
0.050	0					
0.060	0					
0.070	0					
0.080	0					

$\begin{pmatrix} time_{rotor} \\ rotor_{power1} \end{pmatrix} :=$

0.410	0					
0.420	0					
0.430	0					
0.440	0					
0.450	0					
0.460	0					
0.470	0					
0.480	0					
0.490	0					
0.500	0					

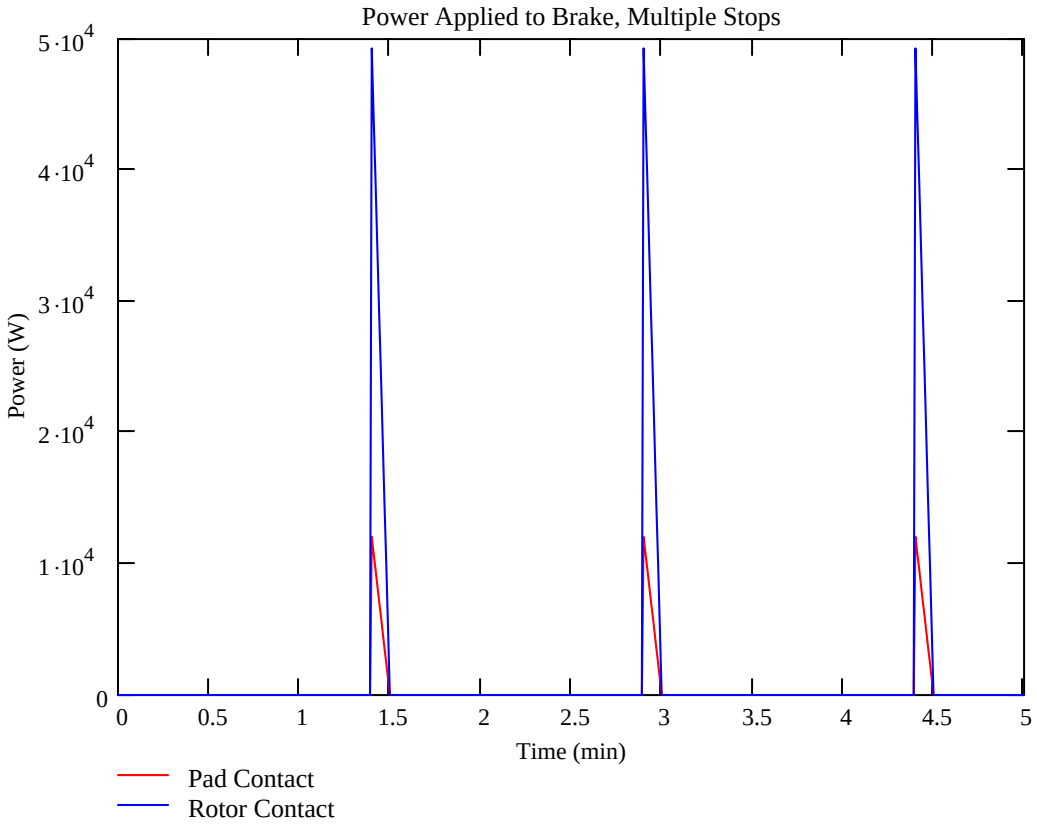


$pad_{power2} :=$

Time (Min)	Power (W)					
0.000	0	0				
0.010	0	0				
0.020	0	0				
0.030	0	0				
0.040	0	0				
0.050	0	0				
0.060	0	0				
0.070	0	0				
0.080	0	0				

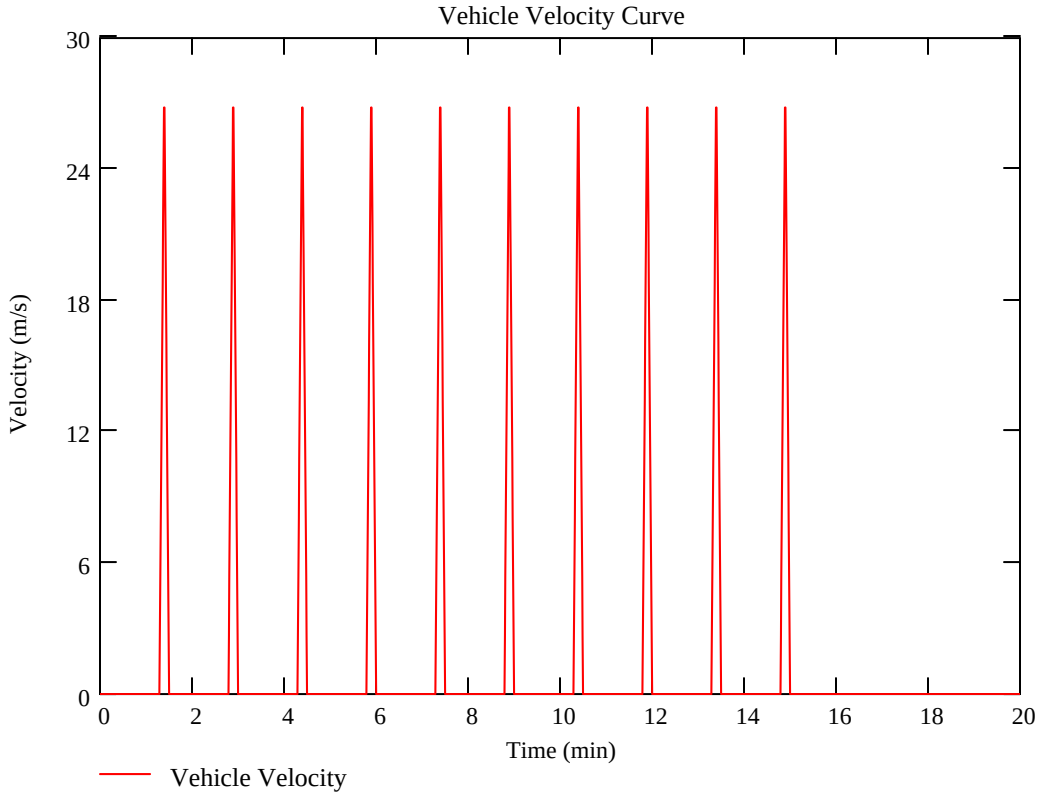
$rotor_{power2} :=$

Time (Min)	Power (W)					
0.000	0	0				
0.010	0	0				
0.020	0	0				
0.030	0	0				
0.040	0	0				
0.050	0	0				
0.060	0	0				
0.070	0	0				
0.080	0	0				



velocity :=

Time (Min)	Velocity (m/s)
0.000	0
0.010	0
0.020	0
0.030	0
0.040	0
0.050	0
0.060	0
0.070	0
0.080	0



convection :=

Time (Min)	Convection (W/m-K)
0.000	5
0.010	5
0.020	5
0.030	5
0.040	5
0.050	5
0.060	5
0.070	5
0.080	5