Finding the Mechanical Advantage of the Braking System



Link C

Link B

Link A

Pedal

Assumptions: Links A, B and C are two force members

Goal: Find the friction force, , applied to the disc based on an applied force, F.

Calculating Friction Force Required for Ideal Stop Time

Assuming a coasting speed of 4 m/s, an ideal gliding stop time is 1.5 seconds, which implies a stop distance of about 10 ft.

Assuming the average mass of the user is 70 kg and the scooter itself weighs 3 kg, the friction force between the rear wheel and the ground that is required for this stop time is 44 pounds.

Calculating Spring Moment

The spring we use on the foot lever applies a moment about point A (see diagram on following page).

At its initial position, the pedal is at 57.9° above the horizontal, and when the caliper contacts the disc, the pedal is at an angle of 50.2°. Therefore, the change in angle from the pedal’s initial position to its suppressed position is 57.9°-50.2° = 7.7°, or 0.134 radians.

Calculating Mechanical Advantage

F

Pedal FBD Equations

y

x

pedal

y

x

pt. A

FAx

FAy

φ

θ

R

Link A and C Equations

Rx

Rx

Link C

Link A

R

R



Disc

Caliper

Link B

Link C

Caliper FBD Equations

w

pt. B

x

FBz

FBx

z

z

Rx

N

Caliper

Assuming an applied force of 50 lb, when the caliper contacts the disc, the normal force is 168 pounds, giving a mechanical advantage of about 3.3.

Calculating Applied Force Required for Ideal Stop Time

The ideal braking force of 44lb is the friction between the rear wheel and the road, however since the radius of the disk’s radius is .62 smaller than the wheel so the friction between the caliper arm and the disk needs to be multiplied by 1.62 giving us 64 lb.

This friction force is dependent on the coefficient of friction (.46) between the disk and the caliper arms. Additionally since the disk is pressed between the two brake pads the friction on the wheel is effectively doubled.

The user has a mechanical advantage of approximately 3.3 so the actual force they need to apply in order to stop in time, our user would need to apply a force of 23 pounds.

Table 1: List of Variables

|  |  |  |
| --- | --- | --- |
| Variable | Description | Value When Caliper Contacts Disc |
| vc | Coasting speed of scooter |  |
| vs | Stopped speed of scooter |  |
| m | Mass of user and scooter |  |
| a | Acceleration |  |
|  | Torque from spring |  |
| k | Spring constant | 4.5 in-lb |
| θ | Angle of pedal from horizontal | 50.2˚ |
| F | Applied force |  |
| R | Resultant force on link A from pedal |  |
| φ | Angle of R from horizontal | 33.6˚ |
| FAy | Vertical resultant force at pt. A |  |
| FAx | Horizontal resultant force at pt. A |  |
|  | Length of pedal from applied force F to pt. A | 2.97 in |
| x | Horizontal distance from R to A | 0.38 in |
| y | Vertical distance from R o A | 0.62 in |
| Rx | Resultant force on Link C |  |
| w | Horizontal distance from pt. B to Link C | 1.72 in |
| z | Vertical distance from pt. B to force N | 1.17 in |
| FBx | Vertical resultant force at pt. B |  |
| FBz | Horizontal resultant force at pt. B |  |
| N | Normal force exerted on caliper from disc |  |
|  | Friction force on disc |  |
| μ | Friction coefficient between disc pad and disc |  |

Table 2: List of Equations

|  |  |  |
| --- | --- | --- |
| Equation Number | Equation | Description |
| 1 |  | Kinematic equation 1 |
| 2 |  | Kinematic equation 2 |
| 3 |  | Newton’s Second Law |
| 4 |  | Hooke’s Law |
| 5 | ,  | Newton’s Third Law |
| 6 |  | Friction Equation |