Performance Optimization Of Hydraulic Brakes In Go-Kart

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Abstract. Go-kart, an agile and elegant vehicle which has become the one from many to acquire basic knowledge of the automobile. Students are very much fascinated towards Design and fabrication of karts to gain hands-on experience. These vehicles encompass all recommended aspects which are involved in lightweight passenger vehicles. Some of the major aspects are likely to be steering, brakes, chassis, transmission system and wheels. Brakes play a crucial role in terms of control and safety. Hydraulic brakes are the only type which aids in achieving minimum stopping distance and time. Use of hydraulic brakes in go-kart became mandatory as the pressurized fluid makes the driver apply less effort. This paper investigated the effect of pedal ratio, manual force and gross weight of the vehicle on stopping distance and stopping time. The result outcomes can be used for the selection of better braking parameter configuration. The reader can choose the value without confusion and design his/her kart accordingly so that it can perform better with ease.

Keywords: Pedal ratio, Manual force, Kart weight, Stopping distance, Stopping time.

1. Introduction
Initially, Go-karts are fabricated for entertainment purpose. As it has four wheels and a single seat with an open cockpit, it appears to be a mini formula. In addition, they are raced on scaled-down circuits. Nowadays, designing and fabrication of go-kart became an interest to the majority of aspiring engineers. To provide guidance and support along with industrial experience, Society of Automobile Engineers (SAE) started organizing national events where students from different institutions all over India can present their karts by manufacturing them in their colleges without exceeding the limits from the rulebook issued by the organizers. Brakes play a major role in the safety of the driver and reliability of the kart. Some of the important parameters should be considered and calculated before installing the brake setup in the vehicle. For example, Pedal Ratio, Manual force, kart weight, stopping distance, stopping time. Every parameter has its significance and has a profound impact on the complete vehicle.

Masood et. al [1] calculated the parameters involved in the braking system by estimating the maximum speed of kart as 118kmph. Prasad et. al[2] given the info on decreasing the speed of the vehicle using kinetic friction and designed a braking system which takes the least time to bring the
vehicle to rest. Ambasha et. al [3] focused on formulating the design of high-performance braking system with considerable stopping distance and made it to meet the general safety requirement. Satyaprakashet. al [4] calculated the design parameters and analyzed the layout of the braking system and brake disc. Saheb et. al [5] provided the braking force to completely lock the wheels at the end of the specified acceleration run and proved to be cost-effective. Now-a-days finite element method is mostly used by researchers [6–13] for design and analysis. In literature, the combined effect of pedal ratio, manual force and kart weight on stopping distance and stopping time is not presented. This necessitates a systematic study for the design of the effective braking system.

In this paper, the comparison is done for all the parameters considered in designing braking system like pedal ratio, manual force and weight of the vehicle. Different alternative inputs have given to those parameters and calculated minimum stopping distance and time which are appropriate for the kart. Graphs have been plotted for those parameters which give the clear description. By considering the rulebook issued by the event organizers. Calculations and comparisons are done without exceeding the limits. Various stopping distances and time have been achieved by changing pedal ratios, manual forces, and kart weights.

2. Methodology
The hydraulic braking system is selected for the present study. Required parameters have been considered to calculate stopping distance and time. Three major parameters have been identified that show the profound impact on the effective functioning of brakes. Four different recurring values of the pedal ratio, kart weight and manual force are varied to examine its effect on stopping distance and time. Block diagram representation of this work is shown in Figure 1.

![Figure 1. Block diagram representation for brake design calculation.](image)

3. Mathematical Formulation
Parameters selected for the calculation are as per rulebook of major SAE events. The gross weight of the vehicle, including driver’s weight, is varied as 150, 160, 170 and 180 kg. Four different values of pedal ratio (3, 4, 5 and 6) and manual force (75, 100, 125, 150 N) are considered in this study. The maximum speed of the vehicle is 80 kmph (22.22 m/s), single and drilled brake disc type with its diameter as 220 mm and thickness as 4 mm, master cylinder piston diameter and calliper piston diameter are 19 mm and 30 mm. Pad thickness is 4.5 mm, Effective radius of the rotor is 110 mm,
coefficient of friction between the brake pad and disc is 0.3 (wet condition) and 0.7 (dry condition).
Force (F) on the master cylinder is the product of the manual force \( F_m \) and pedal ratio (PR).
\[ F = F_m \times PR \]  
(1)
Pressure (P) developed in the system on applying brakes is given by
\[ P = \frac{F}{A} \]  
(2)
Where F is the force applied on the master cylinder and A is the area of master cylinder piston.
Force on calliper \( (F_{cal}) \) is obtained by multiplying pressure exerted inside the system with the area of the calliper. Clamping force applied on the disc will be twice the force on the calliper as the two brake pads present on either side of the disc. Thereafter, clamping force is multiplied with a coefficient of friction in wet condition. Likewise, in dry condition.
\[ \text{Torque on rotor} = \text{frictional force} \times \text{Effective radius of rotor} \]  
(3)
Deceleration (wet and dry) \[ \frac{v^2}{2 \times \text{Deceleration}} \]  
(4)
Stopping Distance (wet and dry) \[ \frac{v^2}{2 \times \text{Deceleration}} \]  
(5)
Where \( v \) is the velocity of the kart.
Stopping Time (wet and dry) \[ v = u + a \times t \]  
(6)
Where \( v \) is final velocity, \( u \) is initial velocity, \( a \) is deceleration.

4. Result and discussions

Three parameters viz. pedal ratio, Manual force and kart weight are studied for improving the functioning of the brake. Result outcomes in terms of stopping distance and stopping time for all the cases considered are presented in table 1-4.

**Table 1. Stopping distance and time for different pedal ratio and Kart weight and Manual force = 75**

| Manual force \( (F_m) \) | Pedal Ratio (PR) | Kart weight (kg) | Stopping distance (m) | Stopping time (sec) |
|---------------------------|------------------|-----------------|-----------------------|---------------------|
| 75                        | 3                | 150             | 41.41                 | 3.72                |
| 160                       | 160              | 44.13           | 3.97                  |
| 170                       | 46.93            | 4.22            |
| 180                       | 49.69            | 4.47            |
| 75                        | 4                | 150             | 31.05                 | 2.79                |
| 160                       | 33.13            | 2.98            |
| 170                       | 35.2             | 3.16            |
| 180                       | 37.27            | 3.35            |
| 75                        | 5                | 150             | 24.84                 | 2.23                |
| 160                       | 26.5             | 2.38            |
| 170                       | 28.16            | 2.53            |
| 180                       | 29.81            | 2.68            |
| 75                        | 6                | 150             | 20.7                  | 1.86                |
| 160                       | 22.08            | 1.98            |
| 170                       | 23.46            | 2.11            |
| 180                       | 24.84            | 2.23            |

**Table 2. Stopping distance and time for different pedal ratio and Kart weight and Manual force = 100**

| Manual force (B) | Pedal Ratio (A) | Kart weight (Kg) | Stopping distance (m) | Stopping time (sec) |
|------------------|-----------------|-----------------|-----------------------|---------------------|
| 150              | 3               | 31.05           | 2.79                  |
| 160              | 33.13           | 2.98            |
| 170              | 35.2            | 3.16            |
| 180              | 37.27           | 3.35            |
Proper functioning of brakes is very crucial for the safety and integrity of the vehicle as well as the passenger. If there is an air bubble present inside the system or any leakage of fluid from hydraulic parts, wheels don’t stop even with maximum manual force or pedal ratio or kart weight. Readers can also decrease the speed and calculate the distance and time using those mathematical models only. Table and graph help to choose the value for parameters accordingly before fabrication of kart.

**Table 3.** Stopping distance and time for different pedal ratio and Kart weight and Manual force = 125

| Manual force (B) | Pedal Ratio (A) | Kart weight (Kg) | Stopping distance (m) | Stopping time (sec) |
|------------------|-----------------|------------------|-----------------------|---------------------|
| 150              | 2.09            |                  |                       |                     |
| 160              | 2.23            |                  |                       |                     |
| 170              | 2.37            |                  |                       |                     |
| 180              | 2.51            |                  |                       |                     |

| Manual force (B) | Pedal Ratio (A) | Kart weight (Kg) | Stopping distance (m) | Stopping time (sec) |
|------------------|-----------------|------------------|-----------------------|---------------------|
| 150              | 1.67            |                  |                       |                     |
| 160              | 1.78            |                  |                       |                     |
| 170              | 1.89            |                  |                       |                     |
| 180              | 2.01            |                  |                       |                     |

| Manual force (B) | Pedal Ratio (A) | Kart weight (Kg) | Stopping distance (m) | Stopping time (sec) |
|------------------|-----------------|------------------|-----------------------|---------------------|
| 150              | 1.39            |                  |                       |                     |
| 160              | 1.49            |                  |                       |                     |
| 170              | 1.58            |                  |                       |                     |
| 180              | 1.67            |                  |                       |                     |

**Table 4.** Stopping distance and time for different pedal ratio and Kart weight and Manual force = 150

| Manual force (B) | Pedal Ratio (A) | Kart weight (Kg) | Stopping distance (m) | Stopping time (sec) |
|------------------|-----------------|------------------|-----------------------|---------------------|
| 150              | 1.86            |                  |                       |                     |
| 160              | 1.98            |                  |                       |                     |
| 170              | 2.11            |                  |                       |                     |
| 180              | 2.23            |                  |                       |                     |

| Manual force (B) | Pedal Ratio (A) | Kart weight (Kg) | Stopping distance (m) | Stopping time (sec) |
|------------------|-----------------|------------------|-----------------------|---------------------|
| 150              | 1.39            |                  |                       |                     |
| 160              | 1.49            |                  |                       |                     |
| 170              | 1.58            |                  |                       |                     |
| 180              | 1.67            |                  |                       |                     |
|       |       |       |       |
|-------|-------|-------|-------|
| 150   | 5     | 150   | 12.42 |
| 160   |       | 160   | 13.25 |
| 170   |       | 170   | 14.08 |
| 180   |       | 180   | 14.9  |
| 150   | 6     | 150   | 10.35 |
| 160   |       | 160   | 11.04 |
| 170   |       | 170   | 11.73 |
| 180   |       | 180   | 12.42 |

Figure 2 (a)–(d). Variation of stopping distance for different values of manual force, pedal ratio and kart weight.
Figure 3 (a) – (d). Variation of stopping time for different values of manual force, pedal ratio and kart weight.

As the kart weight is getting increased, stopping time is increased. To achieve minimum stopping distance and time, kart weight should be low, pedal ratio and manual force should be high. Every parameter is linked with one another. Kart weight causes the result, other two, enhance in attaining less distance and time when they are increased. Above graphs describe the consequence of stopping distance and stopping time by varying pedal ratio, kart weight and manual force. As the parameter value is getting increased, stopping distance and time is rising without any drop. In one case, pedal ratio as 3 and manual force as 100N, in another case, pedal ratio as 4 and manual force as 75N, alike equal results will be obtained for stopping distance and stopping time. Likewise, pedal ratio as 4 and manual force as 100N or pedal ratio as 5 and manual force as 75N. In the same way, pedal ratio as 5 and manual force as 100N or pedal ratio 4 and manual force as 125, approximately similar results will be achieved. Subsequently, testing the vehicle to calculate the stopping distance need not be done at maximum speed. It can also be done at 40 kmph, as the vehicle’s brake capability will be inspected particularly amid economy speed at the events. So finally, all the karts which are getting manufactured should be shifted from mechanical cable brakes to the hydraulic system as they ensure better control and safety of the driver.
5. Conclusion
The parameterized study is carried out using an analytical method. Dataset is generated for four different combinations of kart weight, manual force and pedal ratio. Following conclusive point is obtained from the present investigation:

1) As the kart weight is getting increased, stopping time is increased.
2) To achieve minimum stopping distance and time, kart weight should be low, pedal ratio and manual force should be high.

The only way to make the vehicle stop in less distance is to increase the pedal ratio and manual force as they play a significant role in giving better performance. The heavier vehicle can have optimized hydraulic braking system by using the proper combination of pedal ratio and manual force. The obtained results will help young automobile designers to accomplish the shortest stopping distance and time.

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