Analysis of Skid and Rolling Vehicle

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Abstract. Daihatsu Taf Hiline is one of the cars that are widely used for out-of-town travel, to improve the performance of the car in the field, modified cars, modifications made namely the elevation of the car body. The elevation of the car results in a shift in the center of gravity, so that the stability of the car changes. Changing the stability of the car results in skid conditions and the condition of the car rolling. Data processing calculations using the Vehicle Dynamics Turn method, where previously performed calculations to get the car data, car height, car weight, and the location of the center of gravity. Then do skid analysis and rolling to find out the vehicle dynamics that occur in the vehicle. The calculation result of the maximum speed allowed so as not to skid is 66.16 Km / h and the maximum speed allowed so as not to roll is 32.21 Km / h.

1. Introduction
A car is one of the transportation vehicles that is needed by the community to support daily activities. The need for vehicle safety and comfort is very important, so the material used must be appropriate, as in research [1]–[3] and analysis of vehicle speed, both on a straight road and when turning needs to be done so that maximum speed can be detected so as not to experience danguling skid. This can happen because of the influence of a turning radius, slope angle, displacement of center of gravity and speed, so that a skid and rolling angle occurs which can cause the direction of the vehicle not in accordance with the wishes of the driver, and can be said to be unstable or difficult to control.

The skid condition is a condition where the lateral movement of the wheel disrupts the car, so the car is difficult to control while the rolling condition is a condition where the car's wheels tend to be lifted so that it disturbs the stability of the car, which can cause the car to roll over [4], [5].

Daihatsu taft hiline cars are widely used as passenger cars. Modifications are made by adding pads to the chassis pads that are facing the body of the car. The bearings are 7 cm in size, so the total height of the vehicle increases by 7 cm. The modification aims to make the vehicle compatible with various fields, especially heavy terrain (deep and muddy holes). Modifications affect the stability of the vehicle, to determine the effect of modification on vehicle stability, an analysis is carried out when the car turns on a road with a bend radius, a tilt angle, and a specified vehicle speed. So that it can be seen whether the car has skid and rolling conditions.

The purpose of this writing is to know the condition of the skid and roll the Daihatsu car taft hiline standard and has been modified, at the radius of the turn; 4.01 m, 8.02 m, 16.04 m and 32.08 m, with a slope angle; 5º, 10º, 15º while the vehicle is divorced at speed; 0 to 100 km / h.

Rolling analysis is intended to find the condition of the occurrence of one of which the front or rear wheels are lifted. The lifting of one of the wheels or both wheels shows the possibility of the vehicle being rolled over [5].
The wheel is said to be lifted if the normal occurrence of the wheel is 0 or negative ($F_z = 0$ or $F_z = \text{negative}$). [6]. Skid phenomena occur because of the large lateral force happens to the tire more than the friction force between the tire and road surface [7].

Ease of Use.

### Table 1. Daihatzu Taft Hiline Car Specifications Data[8]

| Vehicle Data | Information | Unit |
|--------------|-------------|------|
| Wide         | 4.580       | mm   |
| High         | 1.580       | mm   |
| Wheel base   | 1.840       | mm   |
| Thread (front / rear) | 2.800   | mm   |
| Ground clearance | 1.320 / 1.300 | mm |
| Weight       | Curb Weight: 1.490 Gros Vehicle Weight: 2.570 Kg |
| Machine      | Diesel; 4 Cylinder; 4 Stroke |
| Capacity     | 2.765       | cc   |
| Diameter x Step | 92 x 104 | mm   |
| Transmission | 5 speed manual; 1 speed reverse. |
| Gear Ratio   | (1) 3,467; (2) 2,136; (3) 1,382; (4) 1,000; (5) 0,860; (R) 4,351 |
| Transfer (Hi / Low) | (Front) axle type; leaf spring; shock absorber double action; stabilizer lateral control rod |
| Suspension   | (Back) axle type; pegas daun; shock absorber double action |
| Transmission | 5 speed manual; 1 speed reverse. |
| Steering wheel | power-steering; ball-nut (24-28) |
| Turning radius | 6.4 mm |
| Tire         | (Front-Back) P 235 65 R 15 89 H |
| Maximum power | 74 PS / 55 kW- 3600 rpm |
| Maximum Torque | 17,5 kgm / 172 Nm – 2200 rpm |

![Figure 1. Daihatsu Taft Hiline](image)

### 2. Description Of Research

#### 2.1. Position of center of gravity

The first step of this research is to find data from vehicle specifications that will be used as input data. After that the calculation is done to determine the distance of the center of gravity of the front, rear and high axle points to get the center of gravity.
2.2. Total car weight
Total car weight (Wt) = 25456.94 Nm
Passenger weight (Wp) 1 person = 637.64 Nm
So that the weight of the car with the driver = 25211.69 Nm
The weight of the front of the car (Wf) = 14891.9 Nm
The weight of the back of the car (Wr) = 10310.3 Nm

2.3. Height Center of gravity

\[ h_r = \frac{(W_f \cos \theta - W_p \sin \theta)}{w \tan \theta} \]  \hspace{1cm} (1)

\[ h = h_r + r \]  \hspace{1cm} (2)

![Figure 2. Position Center of gravity](image)

![Figure 3. Position Height Center of gravity](image)

2.4. Analysis of Skid and Rolling
After knowing the center of gravity is calculated the dynamics of turning the vehicle on a flat road and road with a slope angle of 50°, 100°, 150°

2.5. Analysis Skid Turn on Flat Path
Skid condition is a condition where the lateral movement of the vehicle depends on direction stability. Where the vehicle will experience overster and underster.
The vehicle will be skid if \( F_c > F_g \)

\[ F_c = \frac{MV^2}{r} \]  \hspace{1cm} (3)

\[ F_g = W \cdot \mu \]  \hspace{1cm} (4)
Critical condition if \( F_c = F_g \)

\[
\frac{M V^2}{R} = \mu M g
\]  

(5)

So the maximum speed allowed so as not to skid is

\[
V_{z\text{max}} = \sqrt{\mu R g}
\]  

(6)

![Figure 4. Vehicle dynamics when turning flat[5]](image)

2.6. Analysis of Rolling Turn Flat

Critical condition if \( F_c \cdot h = W \cdot t/2 \)

\[
\frac{M V^2}{R} \cdot h = M \cdot g \cdot \frac{t}{2}
\]  

(7)

So the maximum allowable speed for non-rolling vehicles can be formulated as follows:

\[
V_{g\text{max}} = \sqrt{\frac{F_g}{2h}}
\]  

(8)

2.7. Analysis Skid for roads with slope angles 5°, 10°, 15°

The vehicle will skid if

\[
F_c \cos \theta > (F_g + W \sin \theta)
\]  

(9)

Critical condition if

\[
F_c \cos \theta > (F_g + W \sin \theta)
\]  

(10)

\( F_c \) = Centrifugal force
\( F_g \) = Friction force
\( W \) = Weight
\( \theta \) = Slope angle

The maximum speed allowed so that the vehicle is not skid is

\[
V_{z\text{max}} = \sqrt{\frac{F_g (\mu \cos \theta + \sin \theta)}{(\cos \theta - \mu \sin \theta)}}
\]  

(11)
Figure 5. Vehicle dynamics when turning sideways[5]

2.8. Analysis Rolling against angles 5°, 10°, 15°

The vehicle will roll if

\[ F_c \cdot h \cdot \cos \theta > W \cdot h \cdot \sin \theta + W \cdot \frac{t}{h} \cdot \cos \theta + F_c \cdot \frac{t}{2} \cdot \sin \theta \]

Critical condition if

\[ \cos \theta = W \cdot h \cdot \sin \theta + W \cdot \frac{t}{h} \cdot \cos \theta + F_c \cdot \frac{t}{2} \cdot \sin \theta \]  \hspace{1cm} (12)

\[ F_c \cdot h \cdot W = \text{Weight} \]
\[ h = \text{Height center of gravity} \]
\[ \theta = \text{Slope angle} \]
\[ F_c = \text{Centrifugal force} \]
\[ t = \text{Wheel track width} \]

The maximum speed is allowed so that the wheels are not lifted

\[ V_{g,\text{max}} = \sqrt{\frac{R \cdot g \cdot \frac{t}{2} \cdot \cos \theta + \sin \theta}{(h \cdot \cos \theta - \frac{t}{2} \cdot \sin \theta)}} \]  \hspace{1cm} (13)

3. Result and Discussion

Skid analysis and rolling carried out with a fixed variable is the slope angle of the road 5°, 10°, 15°, the free variable maximum speed is not skid and does not roll.

| Tabel 2. V_{max} Maximum Speed does Not Experience Skid on Flat |
|-------------------|------------------|
| Radius Turn (m)   | V_{max} Not Skid |
| 4.01              | 9.20             |
| 8.02              | 13.04            |
| 16.04             | 18.44            |
| 32.08             | 26.08            |
**Tabel 3.** $V_{\text{max}}$ Maximum Speed Does Not Experience Rolling on a Flat Road

| Radius Turn (m) | $V_{\text{max}}$ Not Rolling |
|-----------------|-------------------------------|
| 4.01            | 11.52                         |
| 8.02            | 16.30                         |
| 16.04           | 23.05                         |
| 32.08           | 32.60                         |

**Figure 6.** $V_{\text{max}}$ Not Skid and Don't Roll on a flat road

Graphs on fig 6 are made based on tables 2 and 3. Known based on these data: Skid conditions occur prior to rolling conditions. The greater the turning radius the higher the maximum allowable speed. Skid conditions occur first because the tire coefficient of friction and road is smaller than the ideal coefficient of friction.

**Tabel 4.** $V_{\text{max}}$ Maksimum Speed Does Not Skid on Roads with Slope Angles, $5^\circ$, $10^\circ$, $15^\circ$

| Radius Turn (m) | Slope Angle | $V_{\text{max}}$ Not Skid |
|-----------------|-------------|----------------------------|
| 4.01            | 5           | 15.59                      |
|                 | 10          | 20.19                      |
|                 | 15          | 27.01                      |
| 8.02            | 5           | 19.09                      |
|                 | 10          | 24.73                      |
|                 | 15          | 33.08                      |
| 16.04           | 5           | 27.00                      |
|                 | 10          | 34.98                      |
|                 | 15          | 46.78                      |
| 32.08           | 5           | 38.19                      |
|                 | 10          | 49.47                      |
|                 | 15          | 66.16                      |

**Tabel 5.** $V_{\text{max}}$ Maximum Speed Does Not Experience Rolling on the Way to the Angle $5^\circ$, $10^\circ$, $15^\circ$

| Radius Turn (m) | Slope Angle | $V_{\text{max}}$ Not Rolling |
|-----------------|-------------|-----------------------------|
| 4.01            | 5           | 9.15                        |

Based on tables 4, 5 and fig 7, 8, it is known that the greater the turning radius, the higher the speed of the vehicle that is permitted when turning. Vmax not skid and rolling are larger at a radius of the turn that is wider with a larger slope angle.
4. Conclusion
The conclusions from the results of this study which are carried out theoretically using the dynamics of turning equations are as follows:

- The maximum speed does not skid the car when turning 66.16 Km / h on a road with a turning radius of 32.08 m and a slope angle of 150.
- The maximum speed does not roll the car when turning 32.21 Km / h on a road with a turning radius of 32.08 m and a slope angle of 150.
- The greater the turning radius and the slope angle of the turn, the higher the speed that is permitted without experiencing skid and rolling.
- The Rolling condition occurs first because the tire and road friction coefficient are greater than \(\frac{t}{2h}\).

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