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Vehicle Testing laboratory Assignment-3

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TITLE:

VEHICLE DYNAMICS

SUB-TITLE:

Static Measurements Test

Executive Summary:

- To calculate the nominal distribution load from front – Rear and Side – Side.
- To calculate the CG location of x, y, z coordinates of the vehicle.
- TO determine the x-y change of the position with passengers in the vehicle.
- To determine the sensitivity analysis of the CG position and produce a 3D plot for x-, y-, z- accuracies and the total lift angle.
- To calculate the spring rates of the front and rear springs of the vehicle.
- To determine the maximum steering angle for each front wheel in both directions and also, to determine steering to road wheel ratio.
- To determine the minimum theoretical turning radius from curb-curb.
- To determine positive or negative chamber and to provide the camber change under rebound.

INTRODUCTION:

Purpose of testing:

- To measure the linear and angular dimensions of the vehicles.
- To measure the vehicle weight.
- For test approvals of each vehicle type.
- To measure the overall usable boot capacity of the vehicle.
- To test the mountability of the parts in the vehicle.
- To test the interior water penetration of a vehicle in the rain chamber.
- To measure and determine the wheel geometry.

General Information About Topic:

- The motion of the vehicle generated by various input actions, through which the vehicle is capable of independent motion. This static measurement explains us about the motion of the vehicle for a given input (steer, weight, camber…), and explains us the mechanics of vehicle motion.
    - These measurements are used to calculate the weight to of a vehicle by placing four corner scales around.
    - The measurements of the linear and angular dimensions of all categories are taken under testing.
    - The spring rate of the vehicle is also calculated by placing different loaded sand bangs in the trunk of the vehicle and weights that are indicated on four corner scales.
    - The ride height of the vehicle is also calculated under static measurements.
    - Even, the center of gravity of the vehicle is also considered under these measurements.
    - The steering angles of a vehicle is also considered by placing vehicle onto front alignment plates of 4-post lift and then, all positions are taken to get the accurate angle.

- The widely used in determining the wheel dimensions and trackwidth of a vehicle.

MATERIALS AND METHODS:

Materials:

1) The testing vehicle during Lab session given was **Mazda RX-8**.
2) For the lift, the **4-post lift machine** was given for elevating one of vehicles using a hydraulic system which is used to calculate the different conditions of a vehicle.
3) The **Sand bag**s are used to test the vehicle under the different weighing conditions.
4) The **Tape measurer** is used to calcite the different ride heights of a vehicle and to determine the C.G of a vehicle.
5) The **Protector** is used to determine the different steering angles in a vehicle.
6) The **Digital inclinometer** is used to determine the Scales under different loading conditions.
7) The **Four corner scales** are used to provide the vehicle weight under loading conditions.

Method:

1) Firstly, the vehicle is placed on the 4-post lift machine and it is lifted up to certain height.
2) With the help of hydraulics in the center, the vehicle is lifted up for placing the 4-corner scales under the tire for recording the weight distribution of the vehicle.
3) For weight distribution, the test is taken under four conditions (no load, passenger, passenger with driver and driver).
4) During the weight distribution the values from digital inclinometer and the tape measurer (ride height) is recorded to know the spring rate and Center of gravity of a vehicle.
5) The front axle of the vehicle is lifted by 4-post lift machine to measure the changes in camber and ride weights of the vehicle.
6) By using the protector for each front wheel, the different steering angles/road wheel configurations are measured (0/360, 90, 180, 270 deg).
7) The vehicle is lifted on 4-post lift machine for easy access to wheels and measure the values of the wheel base and trackwidth of the vehicle.

Results and Discussions:

a) The nominal weight distribution is determined by ratios of the front accelerated weight to rear accelerated weight and side to side.

Where

- RAW is the rear accelerated weight
- FAW is the front accelerated weight

b) The center of gravity of x is determined by RAW/GVW x WHEELBASE.

Where

- RAW is rear accelerated weight
- GVW is gross vehicle weight

c) The center of gravity of y is determined by L.H.S/GVW x TRACKWIDTH.

Where

- L.H.S is left hand side
- GVW gross vehicle weight

d) The center of gravity of z is determined by [WHEELBASE/GVW] x [DELTA OF RAW/Tan (α).

Where

a. GVW gross vehicle weight

1. Use the data from the corner scales to calculate the nominal load distribution (front-to-rear and side-to-side) and CG location (x, y, and z coordinates) of the vehicle.

   i. The nominal distribution weight **front to rear is 52.60 to 47.42 and side to side is 50.47 to 49.55**.

   ii. The CG location (x, y, and z coordinates) of the vehicle.is determined by
   - Centre of gravity of **X is 1271.38 mm.**
   - Centre of gravity of **Y is 1479.55 mm.**
   - Centre of gravity of **Z is 186.073 mm.**

2. The x-y change of the CG position with passengers in the car is determined by

   - Centre of gravity of **X is 1285.27 mm.**
   - Centre of gravity of **Y is 743.78 mm.**

3. Perform a sensitivity analysis of the CG position determination:
   i. Given an accuracy of the scales of +/-ΔW what are the resulting uncertainties ux, uy, uz for the CG position in percent?
   ii. Given an inaccuracy of the measured angle of +/-Δα, what would the corresponding effect on the CG position?
   iii. Produce a 3D plot for x-, y-, and z-accuracy depending on +/-ΔW and the total lift angle α.

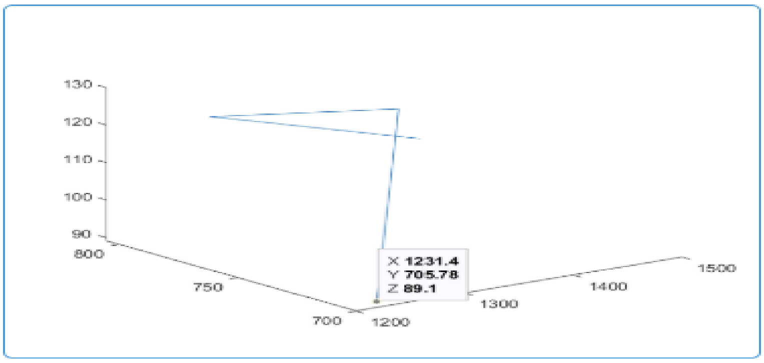
i.&ii.

CONDITIONS	**RAW (kg)**	**FAW (kg)**	**L.H.S (kg)**	**R.H.S (kg)**	**C.Gx (mm)**	**C.Gy (mm)**	**C.Gz (mm)**
Condition-1 (No load)	739.5	606	732.5	613	1489.44	805.47	102.17
Condition-2 Only Driver)	652	761.5	749.5	664	1250.03	784.5	123.53
Condition-3 (Driver with passenger)	757	752	767.5	707	1388.47	768.56	121.85
Condition-4 (Only passenger)	641	770	674	686	1231.4	705.78	89.10

Where

- RAW is the Rear accelerated weight
- FAW is the Front accelerated weight
- L.H.S is Left hand side
- GVW Gross vehicle weight
- RHS is Right hand side

iii. 3D plot for x-, y-, and z-accuracy depending on +/-ΔW and the total lift angle α.



[The 3D plot of the graph determines the different positions of Centre of gravity under different conditions (C.G from ground (y axis), C.G position from right side and left side (x axis)]

4. Use the recorded ride height data for different loads to calculate the spring rates of the front and rear springs of the vehicle. Assume that the two front springs have the same rate, and the two rear springs have the same rate. Write a short MATLAB program that would take in the necessary data from the tests and output the rates of the front and rear springs. Please comment your code accordingly. Does the determined spring rate vary for different lateral positions of the load? If so, what could be an explanation for this?

   - The spring $rate_1$ = 1.82 50 N/mm
   - The spring $rate_2$= 4.5 N/mm

   - After determining the two-spring rate in MATLAB, the obtained values were different. But there is no considerable difference spring rate observed at the rear.

5. Provide the maximum steering angle for each front wheel in both directions. Do they differ? If so, what would be the reason for this? Provide the steering wheel to road wheel ratio. Is the steering gearing linear? Determine the theoretical minimum turning radius following the curb-to-curb definition.

- The steering angle is determined by recorded angle/steering turning angle.

- They differ due to maximum steering angle for suppose if we consider the steering mechanisms (Ackermann steering mechanism).

The steering angles at clockwise direction:

- The Left Front wheel angle at 10deg.

  Left Steering wheel to road ratio at 180deg is 18:1

- Right Front wheel angle at 12deg.

Left Steering wheel to road ratio at 180deg is 15:1

- Left Front wheel angle at 15deg.

Left Steering wheel to road ratio at 270deg is18:1

- Right Front wheel angle at 18deg.

Left Steering wheel to road ratio at 270deg is 15:1

- Left Front wheel angle at 5deg.

Left Steering wheel to road ratio at 90deg is18:1

- Right Front wheel angle at 7.5 deg.

Left Steering wheel to road ratio at 90deg is 12:1

- Left Front wheel angle at 22 deg.

Left Steering wheel to road ratio at 360deg is 16.36:1

- Right Front wheel angle at 24deg.

Left Steering wheel to road ratio at 90deg is 15:1

REASON:

- From the above observations, they have nearly constant steering ratio for the Left front wheel and right front wheel and the steering gearing are linear.
- During recording the observations, at 360deg of turning angle, the Left front wheel was 22deg and the Right front wheel was 24deg.
- By determining the maximum turning angle of the left front wheel has 44deg.

  - The theoretical minimum turning radius of the wheel from curb to curb is determined by ,

  T.R = WHEEL BASE/ Tan (α)

  T.R = 2710/ Tan (30)

  T.R = 4017.74 mm

  Where,

- T.R is the turning radius

6. Do the front wheels exhibit positive or negative camber? How does the camber change under rebound? What is the design reason for this?

Camber in rebound(unloaded) and in ground(loaded):

a) In rebound Condition(un-loaded):

Position of wheel	Angle of camber
Left front wheel	+2.25deg
Right front wheel	+1.25

b) Ground condition(loaded):

Position of wheel	Angle of camber
Left front wheel	+0.5deg
Right front wheel	0deg

ANALYSIS:

- If we observe the above table in both of the conditions, the front wheels determine the positive chamber in rebound condition that is when unloaded weight of the vehicle and during ground condition that is loaded weight of the vehicle. But the camber decreases in ground condition where the front right wheel is observed as zero.

References:

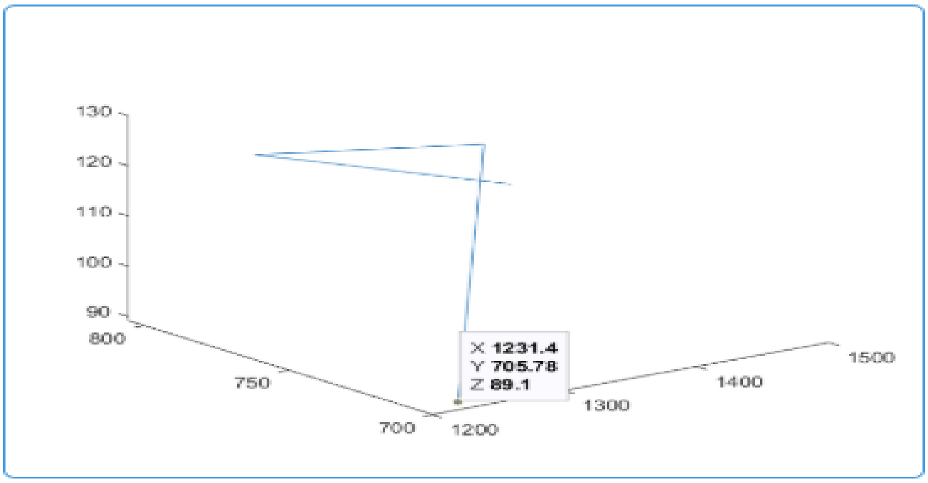
- Static tests of vehicles, machines, equipment and parts (bosmal.eu)
- https://www.garageliving.com/blog/4-post-car-lift/
- https://www.eng-tips.com/viewthread.cfm?qid=104278
- Lab Assignment for VD Lab 1 - Static Measurements.docx

Appendix:

3. Produce a 3D plot for x-, y-, and z-accuracy depending on +/-ΔW and the total lift angle α.

MATLAB SCRIPT:

```
cx=[1489.44,1250.03, 1388.47, 1231.4]
cy=[805.47,784.5,768.56,705.78]
cz=[102.49, 123.53,121.85,89.10]
plot3(cx,cy,cz)
```



4. Use the recorded ride height data for different loads to calculate the spring rates of the front and rear springs of the vehicle. Assume that the two front springs have the same rate, and the two rear springs have the same rate. Write a short MATLAB program that would take in the necessary data from the tests and output the rates of the front and rear springs. Please comment your code accordingly. Does the determined spring rate vary for different lateral positions of the load? If so, what could be an explanation for this?

MATLAB SCRIPT:

```
w.l=[310.0,383.0,429,474]
rideheight=[716,676,637,647]
w1=73
w2=45
rh1=40
rh2=10
springrate1=w1/rh1
springrate2=w2/rh2
```