Design of Chassis Dynamometer for Light Motor Vehicle of Service Stations

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Abstract - *This research paper presents the methodology for the design of a chassis dynamometer for a service station. In chassis dynamometer system, the dynamometer works as an energy absorption device. This chassis dynamometer was designed to determine the condition of the vehicle to conduct different basic tests like acceleration between two Speed points, maximum speed test, different gears speed test, load test, and fuel consumption tests on this. The inertia of the parts plays key role in the part design procedure. The main focus was on lightweight vehicles, therefore in this research, analytical analysis is done these vehicles only. This chassis dynamometer was used to conducts basic test only.*

***Key Words*: Vehicle Data, Chassis Dynamometer, Inertia, Torque, Power, Speed, Vehicle simulated weight.**

1. INTRODUCTION

In the USA, Environmental Protection Agency (EPA) does the annually checking of the trucks and suppliers vehicle. Most of the testing are concerned with optimizing (tuning) the engine management system and straight forward maximum power certification. Above tests complete in short duration by using the chassis dynamometer.

Nowadays, the maintenance of the vehicle is very important. So, this research aimed at service stations. In research, to design a chassis dynamometer this will conduct basic tests of the vehicle. The service stations can reach each and every person; for this reason, to select the service sector.

2. MARKET SURVEY

Now a day, every people are having its own vehicles. Therefore the vehicle maintenance is an important factor of day today life. Before designing of the chassis dynamometer some market survey is important. In this market survey, consider the vehicles which can see maximum on the road.

Table-1: Vehicle Specifications

Company	Model	Track width (mm)	Wheel base (mm)
Hyundai	Acent	1506	2570
	i 20	1760	2570
	i10	1595	2425
Ford	Figo	1680	2491
Maruti Suzuki	Alto K10	1490	2360
	Swift	1695	2430
Honda	Jazz	1694	2530
Tata	Nano	1495	2230
	Bolt	1695	2470
	Vesta	1693	2470
VW	Polo	1610	2469

3. Tests to be conducted

In this chassis dynamometer, to conducts the various tests for the checking of the vehicles. Using this data the worker can solve the problems of the vehicles. Different basic tests like acceleration between two Speed points, maximum speed test, different gears speed test, load test, and fuel consumption test are conducted.

4. PRINCIPLE OF CHASSIS DYNAMOMETER

When the vehicle run at normal condition (on road), the vehicle is in linear motion. And the inertia acts on the vehicle is the weight of a vehicle. But the vehicle test on the chassis dynamometer, linear motion converted into rotational motion, because of the vehicle runs on a roller.

In a linear motion, kinetic energy of the vehicle is

$$K.E. = \frac{1}{2} M v^2$$

In rotational motion, angular kinetic energy of the vehicle is

$$K.E. = \frac{1}{2} I\omega^2$$

Above equations of kinetic energy, therefore it is equal.

$$\frac{1}{2}Mv^2 = \frac{1}{2}I\omega^2$$

$$Mv^2 = I\left(\frac{v}{R}\right)^2$$

$$M = \frac{I}{R^2}$$

$$I = MR^2$$

5. PRODUCT DESIGN

Design constraints are derived from above table. The maximum and minimum track width of the vehicle is 1695mm (Tata Bolt) and 1490mm (Alto K10) respectively. Therefore, arrange the roller assembly as per the track width of vehicle. Similarly to study the wheelbase of the vehicles then decide the length of the ramp of a chassis dynamometer. Maximum wheelbase of the vehicle is 2570mm of Honda Acent. From this study to select ramp length is 3500 mm.

5.1. Transmission Shaft

The transmission shaft is the power transmitting device. There are two types of the shaft one is a solid shaft and other is a hollow shaft. But for calculation, the inertia is directly proportional to weight and inertia is an effective factor in chassis dynamometer. Therefore, there is selecting the solid shaft. To design the solid shaft used material plain carbon steel 40C8.

For this design consider the maximum power is 137 HP at 6800 rpm. Using this data calculate the diameter of transmission shaft is 30mm. but for safety consideration

30 x 1.5 = 45mm

In the calculation of vehicle simulated weight, the weight of the shaft is an increase for this chassis dynamometer. So the diameter can extend up to 60mm.

5.2. Coupling

There are two ways to connect the two rotating shafts one is coupling and other is clutch. There is a basic difference between a coupling and a clutch. Coupling is a permanent connection while the clutch can connect or disconnect two shafts at the will of the operator. A coupling can be defined as the mechanical component that can permanently join two rotating shafts to each other.

For this selecting a flange coupling because of its parameters like torque transmitting capacity, assemble and dismantle construction and for design and manufacture. The rigid coupling is always better than flexible coupling for this research.

A rigid coupling is used to attach two rollers and rollers with a dynamometer. In rigid coupling, the shafts axis must be in straight line. To design the coupling used material plain carbon steel 40C8.

5.3. Ramps

The ramp is used to take off the vehicle on the test platform. There are the two types of the ramp used in this research. One is the straight ramp and other is the inclined ramp.

The straight ramp is designed to use maximum wheel base of the vehicle (Honda Acent 2570mm) and maximum tyre width (Ford Figo 185mm) of the vehicle.

Now to design the inclined ramp this is critical to design. When a vehicle takes off the test platform then the bottom part of the vehicle can touch the extreme point o inclined ramp. Therefore, it designs in a proper manner. The ramp is the manufactured component which is design by a requirement of this research. In designing of the ramp consider the wheelbase and ground clearance (160mm) of the vehicle.

When the vehicle can takes off on ramp then the maximum chances to touch the bottom part in a middle section of the vehicle. Therefore, to consider minimum ground clearance vehicle for an analysis and to construct the model on Solid-Edge ST7 software. Firstly the front wheel of the vehicle is on the straight ramp and rear wheel is on ground. Then draw the line of the bottom of the section and to measure the distance at the extreme point of the inclined ramp. This distance is 40 mm as research.

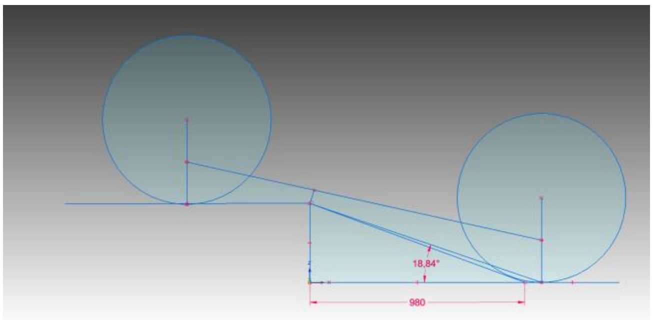

Fig-1: Construction of inclined Ramp

5.4. Roller

Roller design is the crucial part in the chassis dynamometer. When to design roller then remember that the wheels will not jam in the roller and also to manage increase or decrease in the weight as to compensate vehicle simulated weight and total vehicle inertia. These two things are important in the designing of the roller. For the selection of the roller choose standard pipe of mild steel material.

Firstly, to draw the minimum (500 mm) and maximum (620 mm) tire diameter circle and two draw the rollers which diameter is (406.4 mm). Then draw a line passing through the tire center and roller center as shown in a figure. If this line makes an angle 60^0 to70^o then the roller position is correct as per standard of SAJ test Plant. As per construction, the results are 60^0 and 69.06^0. Therefore, this design is correct and the roller center distance is 513 mm.

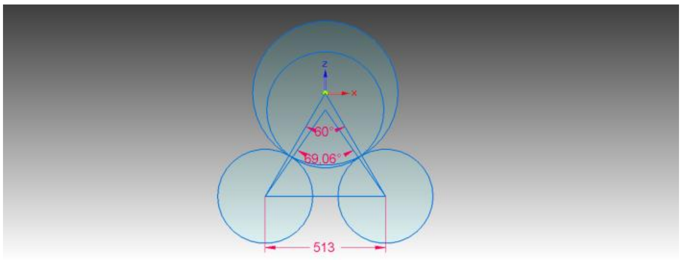

Fig-2: Construction of roller position

Above explanation is about roller position only. Now to turn on its inertia this is very important. Because the roller length and diameter is high therefore its play important role in calculating vehicle simulated weight. The diameter of the roller is 406.4 mm and thickness 25.40 mm. and inertia of each roller is 24.35 kg/m^2.

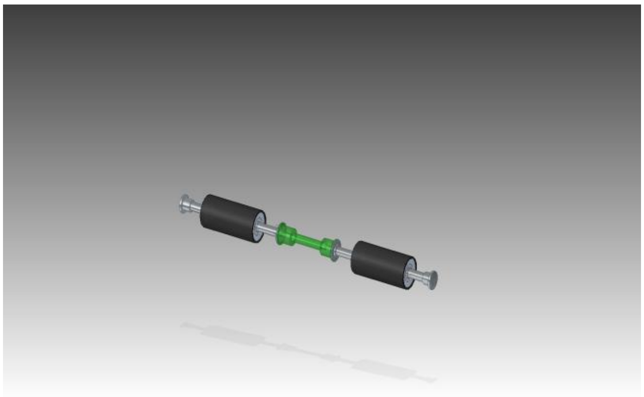

Fig-3: CAD Model of Roller Assembly

5.5 Chequer Plate

Chequer plate is work as covering plate. The material of Chquer plate is mild steel and 5 mm thickness. For the service purpose there are 2 chquer plates which can hold handle. And also the weight of Chquer plate is less than 40 kg.

5.6 Side Roller

The location of side roller is side of the roller. The work of side roller is to prevent the wheel from slippery action on roller.

6. PART SELECTION

6.1. Bearing

Bearings are one of the main parts in shaft assembly. Because the transmission of motion is without friction is most important. For this research use plummer block bearing and pillow type bearing.

Plummer blocks bearing used in the main roller assembly. These bearings have self-mounting points. And also, it can help to maintain center height.

For this research required bearing is sustain at high temperature. To studied the various types of bearing like Plummer block bearing. But this is a failure because of high temperature at the dynamometer shaft. Therefore, the lubricant that is oil is burned out. Therefore, pillow type bearing selected for this research. Pillow type bearings are High temperature (750°C), abrasive, and corrosive, maintenance free.

The transmission shaft diameter is 60 mm then the plummer block can select having bore is also 60mm. and the dynamometer shaft diameter is 40mm. Therefore, the pillow type bearing bore is 40mm.

Transmission Shaft	=	ϕ60 mm
Extended shaft thickness	=	10mm
I.D. of the bearing	=	80 mm
Speed Rating	=	6000 RPM
Actual load	=	1160 kg
Factor of safety	=	2
Total load	=	2320 kg
Total force	=	22759.2 N

Therefore,

For bearing selection process, referring above values

Basic dynamic load rating	=	45000 N
Basic static load rating	=	25000 N

This rating is of SKF bearing.

6.2. Anti-vibration Pad

Increased speed and impact force on the equipment are necessary to meet the manufacturing challenges. And concurrently, vibrations that are present in every industrial application.

There are very easy to relocate the machine. Undesirable vibration cause failures to machines due to fatigue, wear and tear o various machine parts and along with the excessive noise, these can gradually impair normal production processes. Vibration controls necessary to avoid forced deterioration of machinery. There is high precision level and accurate alignment possible. Unique cell design and high coefficient of friction facilitate good adherence to the ground. These are the advantages to using anti-vibration pad.

According to the requirement to select the Screw Support Mount type Anti-vibration Pad.

Highest Mass of the vehicle (Honda Accent) = 1200 kg. Fabrication work and dynamometer assembly = 800 kg. Total Mass = 2000 kg.
Mounting points are 8.
Therefore,
Load carrying capacity of each piece = 250 kg.

6.3. Dynamometer (Air Cooled Type)

There are hydraulic dynamometers, eddy current dynamometers used in the market for the testing of vehicles and engines. Hydraulic dynamometers are power full and it used oil as a coolant. And also its costly than eddy current dynamometer. For this research, Air cooled K-70 Dynamometer is selected which is the type of eddy current dynamometer. Air is used to cool the dynamometer.

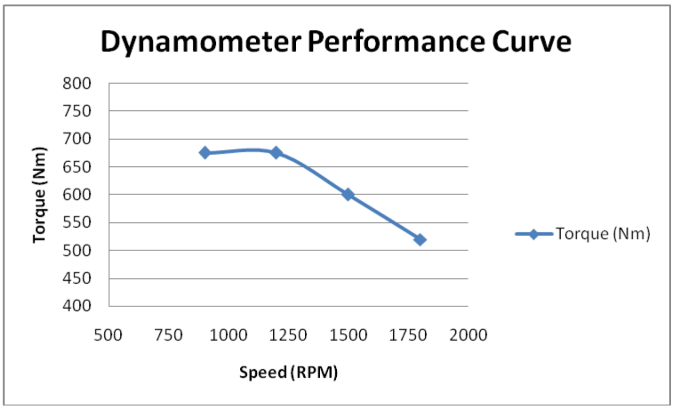

Chart-1: Dynamometer Performance Curve

Above curve is performance curve of the Air-cooled dynamometer. A selection criterion of the dynamometer is torque and power at the specific rpm. If the vehicle's torque and power point locate at the above the dynamometer performance then it cannot work. Approximately vehicles curves are near to the dynamometer performance curve as good as possible. And its power capacity is 150 HP.

6.3.1 RPM at Roller

RPM at the roller is needed to selection procedure of the dynamometer. Because of the dynamometer can be run at certain limit at it response only that RPM. Firstly to find the RPM at wheel by using the following formula,

$$v = \frac{\pi D_1 N_1}{60}$$

From the tire diameter and roller diameter, find out the RPM at wheel of vehicle by using following formula,

$$N_1 D_1 = N_2 D_2$$

By SAE standard, to check the vehicle on the chassis dynamometer at maximum speed 115 km/hr. But for this research take 120 km/hr.

Table- 2: Roller speed and wheel speed

Company	Model	Tyre Dia. (m)	RPM at wheel at 120 km/hr	RPM of Roller at 120 km/hr
Hyundai	Acent	0.5752	1106.66	1566.31
	i 20	0.596	1068.04	1566.32
	i10	0.5782	1100.92	1566.31
Ford	figo	0.596	1068.04	1566.31
Maruti	Alto	0.5316	1197.43	1566.32
	Swift	0.6196	1027.36	1566.31
Honda	Jazz	0.6084	1046.27	1566.31
Tata	Nano	0.4938	1289.09	1580.59
	Bolt	0.6084	1046.27	1566.31
	Vesta	0.583	1091.86	1566.32
VW	Polo	0.6006	1059.86	1566.31

From the table the all roller rpm values are the K-70 dynamometer range.

To calculate torque at wheel

$$T_w = T_e \times i_g \times i_f \times \eta_t$$

For the light weight vehicle, gearbox ratio is between 0.7-1.0 and final transmission ratio in between 3.0-5.5.

In the case of power, the engine power is greater than wheel power because the power losses in the clutch, gearbox and differential. Therefore, in this research consider an engine power.

7. VEHICLE SIMULATED WEIGHT

Vehicle simulated weight is the weight of the system to balance the vehicle and it helps to give exact road condition on the chassis dynamometer. Inertia is an important part of vehicle simulated weight calculation.

There are the following steps are describing the calculation of the vehicle simulated weight

- Calculate the mass of the roller.
- Calculate Moment of Inertia.
- Calculate vehicle simulated weight

Similarly, calculate the vehicle simulated weight for all parts. As per SAE standard, the vehicle simulated weight can be matched to the vehicle weight as the actual inertia acts on the vehicle at road condition is same as the weight of the vehicle.

For this research consider the minimum weight of the vehicle (Tata Nano 710kg). To design this chassis dynamometer minimum weight of the vehicle (Tata Nano 710kg) is considered. And for the other vehicles to add flywheels for increase the simulated weight.

8. FINAL CAD MODEL

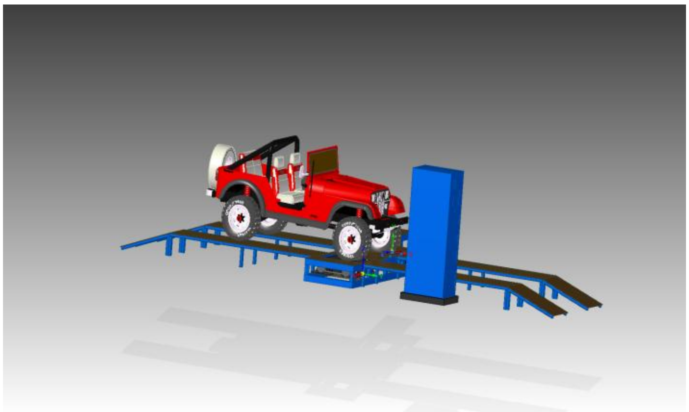

Fig-4: CAD Model of Chassis Dynamometer

Above figure is final CAD model of the chassis dynamometer with the control panel.

Followings are specification of Chassis Dynamometer:

Total Length and Width	8 x 5 m
Total Mass	1200 KG
Total Rotational Inertia	20.21 kg m2
Vehicle Simulated Weight	668 kg
Dynamometer Type	Air-cooled Dynamometer
Max. Speed	2000 RPM
Wheelbase	3500 mm
Track width Range	1300 mm to 1800 mm

9. CONCLUSIONS

Main objective of this research is to improve the performance of light weight vehicles. This design can be done as per analytical calculation. And for designing of chassis dynamometer is completed as per ARAI and SAE standard. This chassis dynamometer designed as per small weight of vehicle. And dynamometer can choose as per highest power of the vehicle at the wheel. Therefore other vehicles test conduct by using the flywheels as per its weight.

10. NOMENCLATURE

M	=	Mass of the vehicle in kg.
I	=	Moment of inertia of the vehicle in kg m^2.
R	=	Roller radius in m.
N_1	=	RPM at the wheel of the vehicle.
D_1	=	Diameter of the tire of the vehicle.
N_2	=	Roller RPM.
D_2	=	Diameter of the roller.
V	=	Speed of the vehicle in m/s.
D	=	Diameter of the tire in m.
N	=	RPM at the wheel of a vehicle.
T_w	=	Torque at wheel
T_e	=	Engine Torque
i_r	=	Gearbox ratio
i_f	=	Final drive ratio
η_t	=	Transmission Efficiency

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