Design of Chassis Dynamometer for Light Motor Vehicle Service Stations

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Abstract— This research paper presents the methodology for the design of a chassis dynamometer for light motor vehicle service stations. 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 is used to maintain the vehicle as per the company standard.

***Keywords*— Vehicle specification, Torque, Power, Speed, Dynamometer, Inertia, Vehicle Simulated Weight.**

I. INTRODUCTION

Now days, light motor vehicles standard has been reached to highest level. The vehicle is the symbol of status in Indian society. The vehicle per individual count has been substantially increased. These vehicles need regular service and maintenance. This research paper is based on the service section of the vehicles. Chassis dynamometer is the testing device. In chassis dynamometer parameters like acceleration, maximum speed, braking distance and brake force can be calculated. In this device linear motion converted into rotational motion. It works on the principle of “Work Energy Principle”.

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.

In chassis dynamometer various test has been conducted and the actions are taken accordingly. It might be very easy and quick service. Different basic tests like acceleration between two Speed points, maximum speed test, different gears speed test, load test, and fuel consumption test are conducted. These tests can help us to maintain vehicle as per company standard.

Chassis dynamometers run some quick test for installed power and check out the chassis and drivetrain [Harold Bettes, 2010]. Several components in dynamometers are the shaft with bearings, the resistance surface, the resistance mechanism in a “free” rotating housing, a strain gage, and a speed sensor [Jyontindra Killedar, 2010]. The road load equation is an important in the R&D type chassis dynamometer. The inertia of the vehicle and the rotating parts of chassis dynamometer are approximately equals [Michael Plint, 2013]. Highway inertia equals the vehicle total effective mass. For light duty vehicles, highway inertia can be estimated by multiplying the vehicle test mass by 1.03 [SAE, 1995]. The wind velocity measurement shall be done at a height of 0.7 m above the road surface. The ambient temperature shall be preferably between 15^0C to 40°C. The speed of vehicle cannot be increase or decrease suddenly. It can do in steps of 20 km/hr during the testing on the bed [BIS, 2000]. The real-world emission data match with chassis dynamometer data, with measurements of speed and acceleration on a large number of vehicles under different driving conditions [Ake Sjijdin, 1995]. The programming on Lab View can control the mechanical and electrical loads for vehicle demand at each speed when the car is acceleration or in constant speed drive [Jirapat Jirawattanasomkul, 2012].

II. Market Survey

For the study, to need the market survey because the market survey can gives the direction to research work. In early years, every people are having its own vehicles. Therefore the number of hatchback and sedan vehicles is increased on road. In company, vehicles are checked on production line. But the vehicles regular maintenance is also important. For this two reasons to choose the category of light motor vehicles and service stations for use of chassis dynamometer.

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

III. WORKING PRINCIPLE OF CHASSIS DYNAMOMETER

When the vehicle runs at normal condition (on road), the vehicle is in linear motion. From this motion the inertia acts on the vehicle. This inertia is equals to mass of a vehicle. But the vehicle test on the chassis dynamometer, the linear motion converted into rotational motion. Because of the vehicle tests are on roller and the rollers having a rotational motion.

In a linear motion, kinetic energy of the vehicle is

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

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.

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

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

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

$$I = MR^2$$

Inertia is calculated to considering the minimum weight of the vehicle.

III. DESIGN OF CHASSIS DYNAMOMETER

Design of any system is divided on two parts. One part is design of components and other is OEM components. In design of components, to design the components from the any of material accordingly its applications. And also considers the various parameters which can affect on the working of components in required condition.

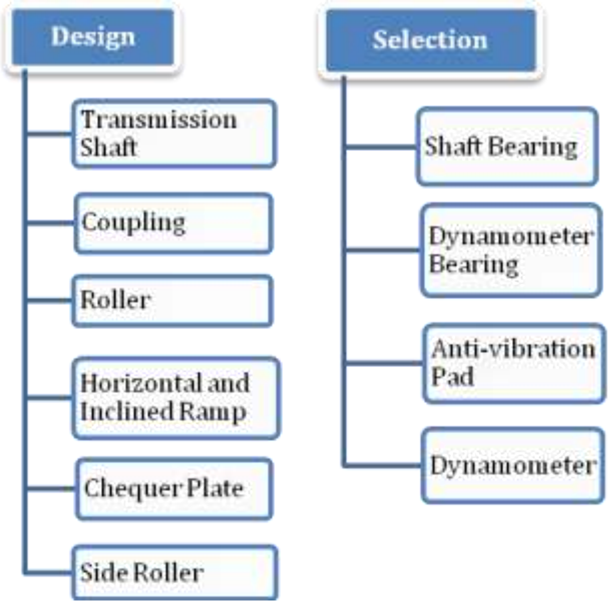

Fig.1 Design of Chassis Dynamometer

IV. DESIGN OF MAIN COMPONENTS

5.1 Transmission Shaft

A transmission shaft is the power transmitting device. To design the solid shaft used material plain carbon steel 40C8. For the design of transmission shaft following data is considered:

Transmitting Power	=	102 kw
Shaft RPM	=	6300 RPM
Torsional Moment	=	154.607 Nm

Using above data calculate the diameter of transmission shaft. The diameter of transmission shaft is 30 mm. but for safety consideration

30 x 1.5 = 45mm

In this chassis dynamometer for the calculation of inertia and vehicle simulated weight, the mass of the shaft is increased. So the diameter can extend up to 60mm.

5.2 Coupling

There are two ways to connect the rotating shafts. One is coupling and other is clutch. There is a difference between a coupling and a clutch. Coupling is a permanent connection while the clutch can connect or disconnect two shafts according to application. Also clutch is more costly as compared to coupling. In this chassis dynamometer coupling is mainly used. A coupling can be defined as the mechanical component that can permanently join two rotating shafts to each other.

Flange coupling is one of the type of coupling. This is mainly used in the design of chassis dynamometer for connecting the shafts. It has high torque transmitting capacity, assemble and dismantle construction easily.

The flexible coupling is always better than rigid coupling for this research. It can tolerate 0.5 mm of lateral or axial misalignment and 1.5^0 of angular misalignment. And also it prevents the vibration from one shaft to another shaft. In this chassis dynamometer a flexible coupling is used to attach two rollers and rollers with a dynamometer shaft. To design the coupling plain carbon steel 40C8 is used.

5.3 Ramps

The ramp is used to take the vehicle on test platform and landing on floor. There are the two types of the ramp used in this chassis dynamometer. One is the horizontal ramp and other is inclined ramp.

To design horizontal ramp, maximum wheel base of vehicle (Honda Acent 2570mm) and maximum tyre width (Ford Figo 185mm) of vehicle is used.

The inclined ramp is critical to design. Therefore, it should be design in a proper manner. The ramp is manufactured component which is designed according to the requirement of the research. In designing of the ramp, consider the wheelbase and minimum ground clearance (160mm) of vehicle.

In this operation, there are maximum chances to touch the bottom part of vehicle in a middle section. Therefore, it is required to consider minimum ground clearance vehicle. For an analysis, the construction is done on Solid-Edge ST7 software. Firstly the front wheel of the vehicle is on the horizontal ramp and rear wheel is on ground. Then draw the line which is imaginary line of bottom part of vehicle. After finishing the constructions, measures the distance between an imaginary line and the extreme point of the inclined ramp. This distance is 40 mm as per construction. This is sufficient distance to avoid the damage of vehicle.

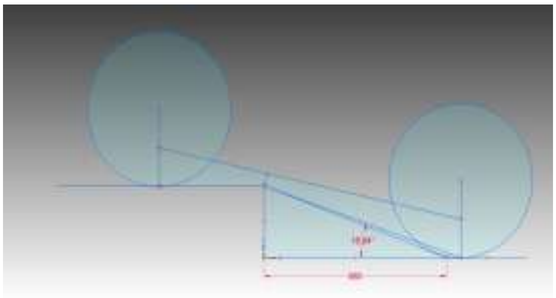

Fig.2 Construction of inclined Ramp

5.4 Roller

Roller design is a crucial part in the chassis dynamometer. In designing of roller, the vehicle should be taken that that wheels should not jam between the rollers and trackwidth of various vehicle should manage properly. These two things are important in the designing of the roller. Maximum standard parts should be use in designing of system. Therefore the rollers are selected from standard mild steel pipe.

Roller is a major component in vehicle simulated weight. Because the maximum simulated weight can cover by roller. From the study of standard pipes and its simulated weight, it is conclude that to select a standard pipe having diameter 406.4 mm and thickness 25.40 mm. The roller having a knurling for tire grip and its depth could not exceed than 0.5 mm.

Firstly, to draw a circle this has minimum (500 mm) and maximum (620 mm) tire diameter. And then draw the two circles which is roller diameter (406.4 mm). Then draw a line passing through the tire center and roller center as shown in a figure. If the angle between tire centre and roller center is 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 construction is correct and the position of the roller is fixed. The distance between two roller centres in side view is 513 mm.

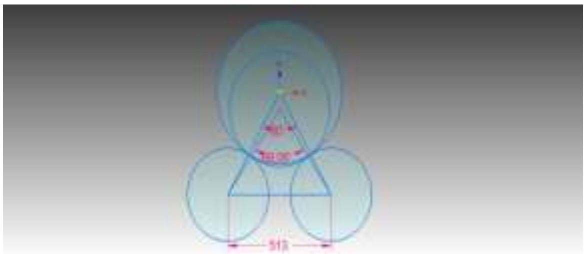

Fig.3 Construction of roller position

Fig.4 CAD Model of Roller Assembly

5.5 Chequer Plate

Chequer plate is working as cover of test platform. Chequer plate mounted on the frame of chassis dynamometer. The material of Chequer plate is mild steel with 5 mm thickness. There are various sizes of chequer plate as per system set up. But the weight of Chquer plate must be less than 40 kg for an easy handling purpose.

For the service purpose there are three chequer plates which can easily open. This chequer plates are having a handle for a holding purpose.

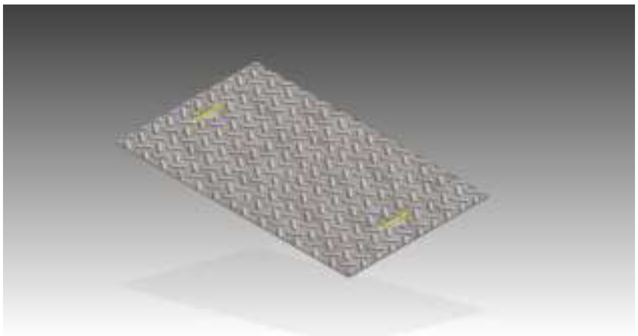

Fig.5 Chequer Plate

5.6 Side Roller

The side roller is located at the edge of main roller. This helps us to avoid sideways moment of wheel roller. There are two types of side roller. One is cylindrical and other is conical shape. But there is not major difference between them. For this chassis dynamometer conical shape side roller is used.

Fig.6 Side Roller

V. SELECTION OF COMPONENTS

6.1. Bearing

Bearings are one of the main parts in shaft assembly. Because the transmission of power is without friction is done by the bearing.

Plummer blocks bearing are used in the main roller assembly. In this type of bearing housing is different and bearing is different. The bearing is self aligning type bearing. This bearing is capable to handle misalignment in the shaft. The operating temperature o bearing is -40^0-100^0c. The plummer block having self-mounting points.

The selection of bearing of dynamometer is critical. Because the dynamometer shaft temperature is high as compared to rollers shaft. For this research required bearing is sustain at high temperature. To studied the various types of bearing like self aligning bearing, angular bearing. The lubricant in the bearing is burned out because of high temperature of shaft. Therefore, pillow type bearing selected for this research. Pillow type bearings are sustain in condition of high temperature (750℃). Also it is abrasive, and corrosive, maintenance free bearing.

For this research plummer block with self-aligning bearing and pillow type bearing is used.

Fig.7 Pillow Type Bearing

The transmission shaft diameter is 60 mm. So the plummer block with self-aligning bearing is select having bore is 60mm.

Transmission Shaft = ϕ60 mm
Speed Rating = 4000 RPM
Total load = 2139 N
Basic dynamic load rating = 35000 N

The dynamometer shaft diameter is 40mm. Therefore, the pillow type bearing bore is 40mm.

Transmission Shaft = ϕ40 mm
Speed Rating = 4000 RPM
Total load = 2139 N
Basic dynamic load rating = 30000 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.

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. There are very easy to relocate the machine. These are the advantages to using anti-vibration pad.

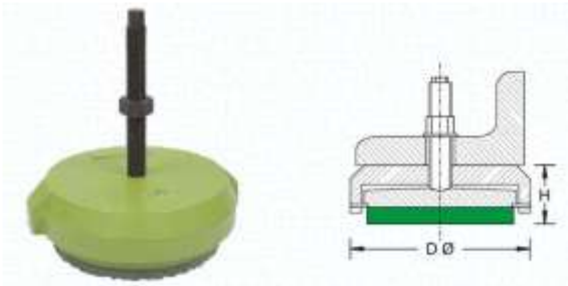

Fig.8 Anti-vibration Pad

According to the requirement to select the screw support mount type anti-vibration pad. This type of anti-vibration pad having a height adjustment system. It can adjust the system height up to 10mm. it is provided leveling purpose.

Highest Mass of the vehicle (Honda Accent) = 1200 kg. Fabrication work and dynamometer assembly = 1200 kg. Total Mass = 2400 kg.

Mounting points are 8.
Therefore,
Load carrying capacity of each piece =300 kg.

6.3. Dynamometer (Air Cooled Type)

The dynamometer is an energy absorption device. There are hydraulic dynamometer and eddy current dynamometer mostly used for the testing of vehicles and engines. The power of Hydraulic dynamometer is high as compare to other types of dynamometer and the oil is used as a coolant. Hydraulic type dynamometers are costly because the coolant system and its accessories. The air Cooled dynamometer is not much costly as compared to hydraulic dynamometer. There is another type of eddy current dynamometer is water cooled type dynamometer. In this dynamometer water is used as a coolant. Therefore coolant system is added on system so the cost increased.

From the above study is to select air-cooled dynamometer. In this air is used as coolant. The air is used in atmosphere; therefore there is no need of any system related to coolant.

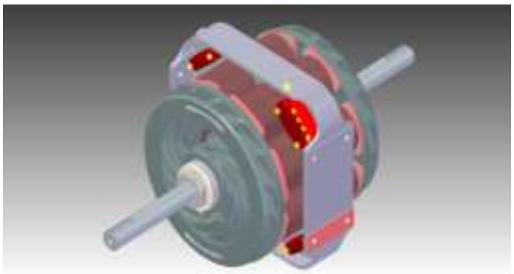

Fig.9 Air Cooled Dynamometer

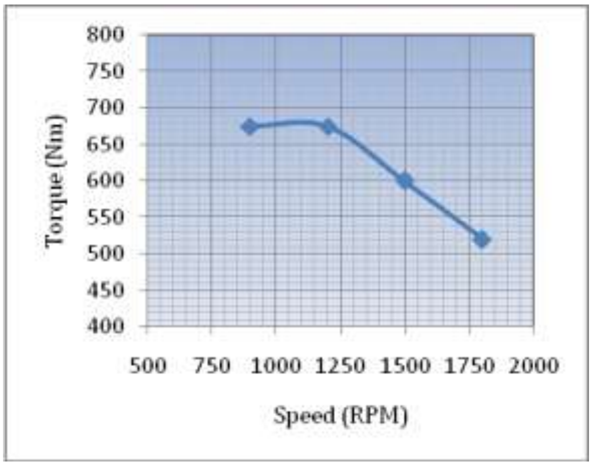

Fig.10 Dynamometer Performance Curve

- RPM at Roller

RPM at the roller is needed for selection procedure of the dynamometer. Because of the dynamometer is runs at certain limit at it responded bellow 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 for a safety.

Table- 2: Roller speed and wheel speed

Company	Model	Tyre Dia. (m)	RPM at wheel of 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.

VI. VEHICLE SIMULATED WEIGHT

Vehicle simulated weight is the weight of the system to balance the vehicle and it helps to give exact road condition for a testing on the chassis dynamometer. Inertia is an important part for the calculation of vehicle simulated weight. There is the following steps are describing the calculation of the vehicle simulated weight

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

As per SAE standard, inertia acts on the vehicle by motion at road condition is same as the weight of the vehicle. The vehicle simulated weight can be matched to the vehicle weight. To design this chassis dynamometer minimum weight of the vehicle (Tata Nano 710kg) is considered. And for the other vehicles matching simulated weight by add flywheels.

VII. RESULTS AND DISCUSSIONS

8.1. Final CAD Model

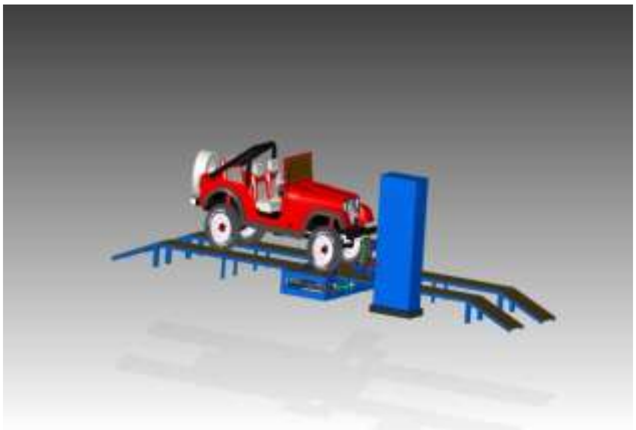

Fig.11 CAD Model of Chassis Dynamometer

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

8.2 Specification of Chassis Dynamometer

Total Length and Width	8 x 5 m
Total Mass	1200 kg
Total Rotational Inertia	20.21 kg m^2
Vehicle Simulated Weight	668 kg (Minimum)
	1200 kg (Maximum)
Dynamometer Type	Air-cooled Dynamometer
Max. Speed	2000 RPM
Wheelbase	Up to 3500 mm
Track width Range	1300 mm to 1800 mm
Class of Vehicle	Hatchback and Sedan
Power of Vehicle	Up to 137 HP
Torque of Vehicle	Up to 600 Nm

VIII. CONCLUSIONS

Main motive of the 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, BIS and SAE standard.

The total inertia of the vehicle in motion is equals to the vehicle total effective mass. The minimum weight vehicle is Tata Nano (710kg). This weight can be match with the simulated weight of the rotating parts of chassis dynamometer. From the research the simulated weight of chassis dynamometer is 667.25 kg. And for other vehicles, the flywheel is added accordingly vehicles weight.

Dynamometer can choose as per highest power and torque of the vehicle. The highest power and torque of the vehicle is 137 HP and 250 Nm respectively. The selected dynamometer is 150 HP and 525 Nm at 1750 rpm.

As per SAE standard the vehicle runs at 115 km/hr and from BIS vehicle runs 60 km/hr. Therefore the vehicle runs roller 1100.92 rpm and roller runs at 1580.89 rpm.

From the above study, the designed and selection of components are 4000 rpm.

IX. 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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