Steering Effort Calculation Methodology & Study On Hydraulic And Electronic Power Steering

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***Abstract*-** *The steering effort is an important characteristic of vehicles because it influences driver comfort directly. Steering effort and steering feel are of interest in this research paper. Steering feel, a driver's perception of steering characteristics, has become an important issue in recent years. Steering effort according to the vehicle speed and steer speed is directly affecting the steering feel and driving comfort. Steering effort can be conveniently divided into parking maneuver and driving maneuver categories. Steering effort on parking and on driving maneuvers is generated by different procedures. In a parking maneuver, steering effort is developed due to the elastic deformation of the tire tread due to the friction between tire surface and ground. In a driving maneuver the slip angle concept is an essential factor in analyzing steering effort. As the axel weight increases the steering effort also increase, after a certain limit it is impossible for human muscle to steer the wheel for longer span of time. To overcome this, power steering attachments are introduced which can either be hydraulic pump or electric motor, assisting the steering gear box. Both of the steering gear attachments are discussed in this research paper.*

***Keywords*-** Chassis load distribution, Electronic power steering, Hydraulic steering pump, Steering effort.

I. INTRODUCTION

Static steering torque is usually described by the feedback of steering wheel torque, which includes the internal friction torque of steering system, the gravity aligning torque generated by vertical force, and the tire-patch sliding torque (tire-patch sliding torque is the sliding torque acting on the tire–road contact patch). The tire-patch sliding torque is usually regarded as static steering torque for simplicity because it accounts by far for the largest proportion of it. The steering hand wheel torque needed to move the road wheels slowly against various forms of resistance at very low or zero vehicle speed is an important case in the design of a car steering system. It influences the choice of steering gear ratio, whether or not power assistance is necessary and the nature of such power assistance, if any. The present increasing use of electrical assistance and new considerations of "steer by wire" systems make the subject topical, although there seems to be little recent relevant literature. The torque required to steer the road wheels of a car is a maximum when the car is stationary, so this is the case considered. In addition to this interaction, the steering geometry and the friction forces in the system influence the torque necessary. [1] To understand the calculation method for steering effort a Typical N1 class vehicle (with front steered wheels, coil type independent suspension) is considered with relevant loads of different components on the chassis. The process of calculation will start with load distribution over the chassis and the calculation of reactions at front axle and rear axle. [2]

II. STEERING EFFORT CALCULATION INPUTS

To calculate the steering effort we require inputs as listed

1. Tyre Width (with reference to tyre designation).
2. Front Axle Weight
3. King Pin Off-set on Ground (scrub)
4. Steering Arm Length
5. Drop Arm Length
6. Gear Box Ratio
7. Steering Wheel Diameter

Starting with Tyre Width which is considered with reference to the tyre designation, here we have considered a 7X16 Bias tyre with tread width as 150mm. It should be noticed that only the tread width comes in contact with the road and the sectional width of the tyre is not the tread width, as shown in Fig 1, sectional width is always greater than the tread width.

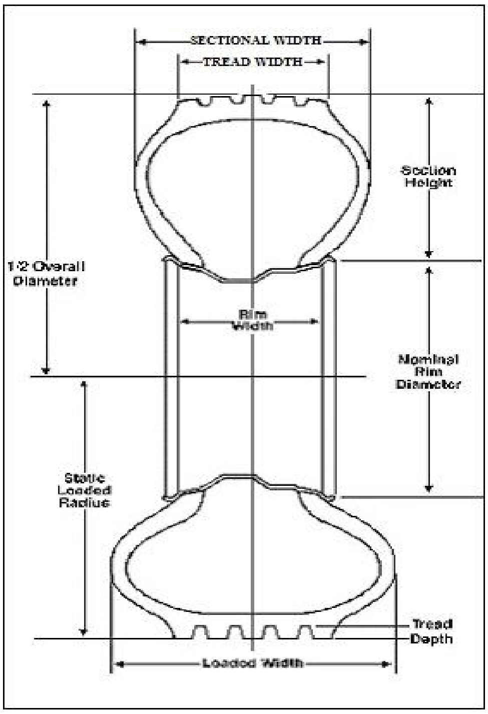


Fig-1 Sectional View of Tyre

Moving on to the front axle weight calculation, it is calculated as the reaction force which is a resultant of all the loads applied on the chassis, with reference to Fig 2 these major applied loads are : A- Front bumper, B-1st Body Mounting, C-Radiator ,D-Engine ,E-2nd Body Mounting ,F-Steering system ,G-Gear Box ,H-Chassis (uniformly distributed load) ,I-Fuel Tank mounting ,J-Fuel Tank mounting ,K- 4th Body Mounting.

R1 is Reaction at Front Axle and R2 is Reaction at Rear Axle. The reaction at the front axle is considered as Front Axle Weight (FAW). Considering a N1 vehicle with Gross vehicle Weight as 3000 kg, FAW is taken around 1100 kg.

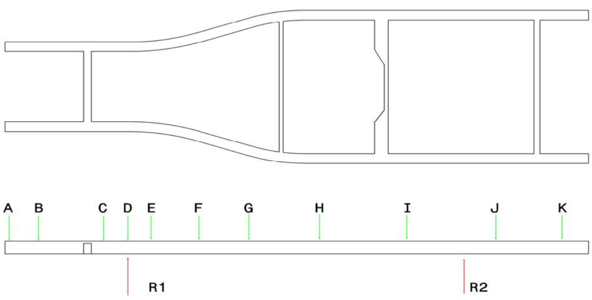


Fig-2; Load Distribution on Chassis

King Pin Off-set on Ground (also called scrub radius) taken as 60 mm. At zero scrub radius, the car steers easily and will have little or no kickback from bumps. At the same time there will be virtually no road feel or feedback and there will be a feeling of directional instability while cornering due to the tendency of the tires to squirm. This condition is also known as centre-point steering. A positive scrub radius will increase steering effort, torque steer and kickback on bumps to a considerable degree. At the same time, a blowout or a failure of one front brake could yank the wheel hard enough to pull it out of your hands. The advantage is that there is much greater road feel and feedback so that you can feel when the front tires start to break loose in a corner. Consequently, this is often the set-up of choice on race cars. Negative scrub radius will also increase steering effort, torque steer and kickback but to a noticeably lesser degree than the positive kind. Additionally, front tire blowouts and single brake failures will act with less force on the steering wheel. Finally, there will be less road feel and feedback and less ability to feel when the front tires are about to break loose as compared with the positive state. In general, front-wheel drive cars are set-up with negative scrub radius. Incidentally, the term scrub radius derives from the fact that either in the positive or negative mode, the tire does not turn on its centerline (it scrubs the road in a turn) and due to the increased friction, more effort is needed to turn the wheel.

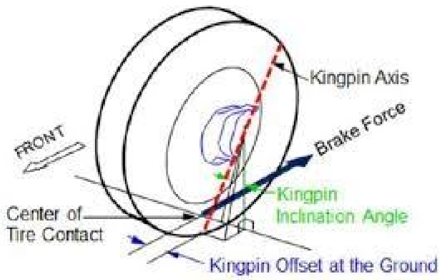


Fig-3; Scrub Radius

Length of Steering Arm and Drop Arm are considered as 203 mm and 225 mm respectively with reference to N1 category vehicle. A steering box with 18:1 gear ratio is considered which can be power assisted and a 200 mm radius Steering Wheel is taken, which is generally ergonomic. [3]

III. CALCULATION

$$T = W \, x \, f \sqrt{\frac{B^2}{8} + E^2}$$

T = Total Kingpin Torque required to steer axle.

W = Vehicle Weight supported by the steered axle.

F = Coefficient of friction (dimensionless). 0.7 as a Maximum.

B = Nominal width of the tire print (tread width).
E = Kingpin Eccentric (use nominal tire width).

Table-1; Steering Effort without Power Assistance

INPUT		UNITS
TREAD WIDTH	150	mm
FRONT AXLE WEIGHT	1100	kg
FRICTION FACTOR	0.7	
KING PIN OFF-SET ON GROUND	60	mm
STEERING ARM LENGT	203	mm
GEAR BOX RATIO	18	
DROP ARM LENGTH	225	mm
STERING WHEEL RADIUS	200	mm
OUTPUT		
TORQUE AT SECTOR SHAFT 'T'	61660.13	kg mm
FORCES ON DRAG LINK	303.74	Kg
STEERING TORQUR	68342.51	kg mm
STEERING SHAFT TORQUE	3796.81	kg mm
EFFORT ON STEERING	18.98	kg

From the above calculations we have obtained that, 18.98 kg of effort is required to steer the vehicle in static condition with the said inputs. It is well understood that the effort required is high and is difficult for human muscle to provide the same at constant rate for long duration. Possible solution to this problem is Hydraulic Power Steering.

IV. POWER STEERING

The turning movement of the wheels is exclusively mechanic, which is assisted by the hydraulic power generated by the steering pump. The control valve is made out of a rotating poppet mounted onto needle bearings inside the ball screw nut, that part of the screw acting as a dowel (Fig 4). Six grooves are made onto the rim of the poppet in regards of six grooves corresponding on the dowel. When the steering wheel is turned, the poppet is solicited in rotation and drives in its movement the ball screw nut. This synchronization is realized through the torsion bar that is pined to the screw on one end and to the poppet at the other. This bar maintains the control valve in a neutral position without solicitations on the steering wheel. A torque can be applied either from the steering wheel onto the rotating poppet, or from the wheels onto the ball screw. In the two cases the torsion bar is deforming in its elastic domain and a relative rotation between the dowel and the poppet is appeared. The control valve is put in a working position and the inlet valves towards one of the cylinder chamber are open. The piston displacement induces the turning of the wheel. Then the pump is the component that allow to put the fluid into movement at a given flow rate. That flow rate is calibrated in function of the steering gear and the pressure losses generated by the circuit in order to have the necessary hydraulic power to provide an efficient assistance.

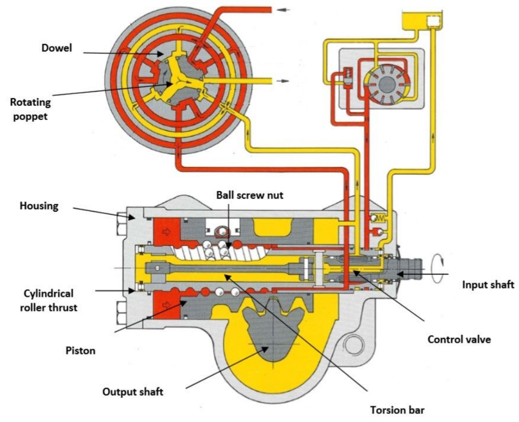


Fig 4; Sectional View of Power Steering Assembly

The technology used is a rotary vane pump of fixed capacity, driven by the crankshaft through a gear. This technology has the advantage to be cheap, but the fixed capacity requires designing the pumps so that they provide the required flow rate from the lowest engine speed. Therefore an important part of the flow rate has to be recycled inside the pump's housing itself in order to maintain the flow rate at a given value when operating the engine on its range of speed. Thus a control flow valve and a pressure relief valve are integrated to the pump design. The direct consequence of that recycled flow is an overheating of the steering oil. The oil tank, and its filter, enables to guarantee permanent oil feeding to the pump and to preserve the circuit's elements of particles intrusion. On the other hand the filter is generating a non-negligible pressure loss (around 1 bar). Finally, as shown in 'Fig 5' the elements are linked together with piping elements flexible or rigid. [4]

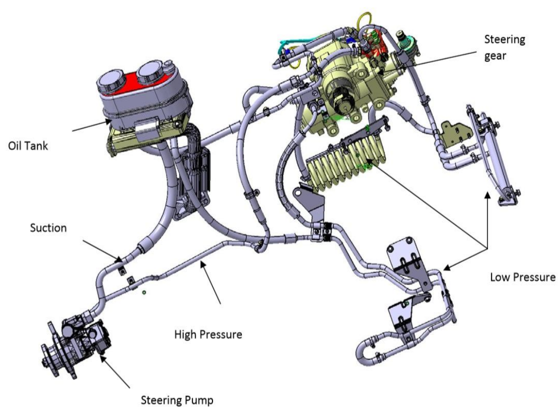


Fig-5; Assembly of Power Steering

IV. POWER STEERING CALCULATION

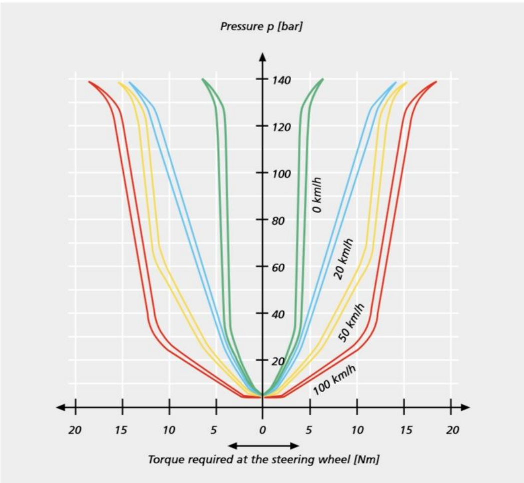
As we have 18.98 kg effort which is required to turn the wheel at static contrition, the steering pump will assist and will reduce the effort to near about 70% to 80%.

For every steering mechanism which is powered, an optimum Pressure vs Torque is provided for the sector shaft, here in this research we have considered it as at 70 Bar – 808Nm Torque is generated.

Table-2; Calculation with Power Assistance

INPUT		UNITS
TORQUE AT SECTOR SHAFT 'T'	61660.13	kg mm
FORCES ON DRAG LINK	303.74	Kg
STEERING TORQUR	68342.51	kg mm
STEERING SHAFT TORQUE	3796.81	kg mm
EFFORT ON STEERING	18.98	kg
OUTPUT		
TORQUE AT SECTOR SHAFT 'T'	604.89	Nm
FOR 70 BAR - 808 Nm TORQUE, FOR 604.89 Nm TORQUE, WHAT WILL BE THE VALUE OF PRESSURE.	52.40	Bar
FROM THE GRAPH, FOR 52.40 BAR THE VALUE OF TORQUE AT STEERING WHEEL WILL BE	4.7	Nm
TORQUE AT STEERING WHEEL	479.10	kg mm
EFFORT ON STEERING	2.40	kg

Refer Graph-1, for Torque required at steering wheel at 54.40 Bar for '0' kmph.



Graph-1; Steering Wheel Torque vs Pressure

V. ELECTRIC POWER STEERING (EPS)

Electric power steering (EPS) system controls the motor drive torque by precise current adjustment based on steering torque signals detected with torque sensor and provides vehicle drivers with fine steering assist according to the state of vehicle operation. Consuming power only when steering assist is necessary, it is more fuel efficient than the conventional hydraulic power steering system. [5]

Brush motors are driven by control unit (ECU) to supplement the torque to steering mechanism in EPS system for driver assistance

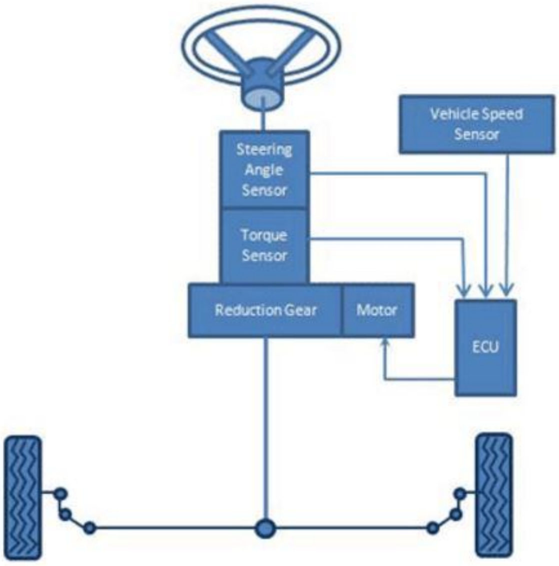


Fig-6; Electronic Power Steering

Benefits of EPS

1. Construction and design of EPS system is simple and easy as compare to conventional power steering systems. Only battery connection is needed for the work output.
2. Smaller and light weight structure due to elimination of many components such as valve, pumps and hydraulic lines.

VI. CONCLUSION

From the above calculation it is clear that for heavy loads power assistance to the steering mechanism is required, further is understood that electronic power steering is more efficient than hydraulic power steering.

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