

# TECHNICAL PAPERS

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### On-center Steering Response

On-center steering response is one of the important parameters which is closely related to the measure of steering response during high speed lane change or road maneuverability [24]. It is estimated by measuring the degree to which road wheel turns when steering wheel is rotated by 90° towards LH and RH side. Plot of steering wheel rotation vs road wheel turn (RH wheel) of existing system and new system is shown in Figure 7 and Figure 8 respectively. Based on the benchmark data, it was found that the vehicle handling was found to be better when the steering wheel is rotated steering ratio is between 20:1 to 25:1. Comparison of on-center steering response between existing and new design is tabulated in Table 3. It was found that the on-center response of the new design was slightly higher than the existing system. However, both the systems meet the requirement.

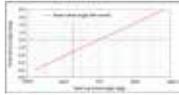


Figure 7. Graph showing steering wheel rotation vs road wheel turn existing design.

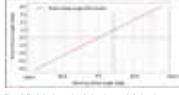


Figure 8. Graph showing steering wheel rotation vs road wheel turn new design.

Table 3. Comparison of on-center steering response between existing design and new design.

Parameter	Existing Design	New Design
Steering Ratio	20:1	25:1
On-center Steering Response	0.2	0.25

### Steering Gear Demand Torque Comparison

An attempt was made to compare the steering gear demand torque values between the existing steering system and new steering system. It is the torque required at the steering gear when the road wheel is at

the first or last condition for the study was 0 degree. Torque required to turn the road wheel about the kingpin was estimated. The tire to road friction coefficient was 0.8. Kingpin torque estimated was used as a reference torque to determine the steering gear demand torque in the existing and new steering system. For the equivalent design, equal torque demand torque from the steering gear was estimated. The kingpin torque and steering gear demand torque values of both the systems are tabulated in Table 4. It can be seen that for the same kingpin torque, the steering gear demand torque has increased from 400 N-m to 577 N-m in the new system which is approximately 22% lower than the existing. This will in turn reduce the steering wheel effort to be exerted by the driver to steer the vehicle.

Table 4. Comparison of steering gear demand torque between existing and new system.

Parameter	Existing Design	New Design
Kingpin Torque	400 N-m	400 N-m
Steering Gear Demand Torque	400 N-m	577 N-m

### Structural Analysis of Drag Link

Finite element analysis was carried to study the force-displacement characteristics and modal frequencies of the draglink using ANSYS 14.5. FE model of drag link is shown in the Figure 9. Non-linear buckling analysis (one length method) was carried out to estimate the critical buckling load. The boundary conditions defined were, all the three translational degrees of freedom were constrained at one end of the link and it was free to rotate in any direction. At the other end, displacement load was applied along X-axis and other two translational movements were constrained. It was free to rotate about Y and Z axis but constrained to rotate about X-axis.



Figure 9. FE model of the drag link.

The force vs displacement analysis of the drag link is shown in the Figure 10. It can be seen from the plot that the drag link tube becomes unstable only after 47.4 kN when the design requirement is to have buckling strength of about 31.2 kN. So, the design was successfully safe. Three samples of draglinks were tested for validating the



Figure 10. Force vs displacement plot for drag link tube.

Table 4. Buckling strength values of the drag link samples.

Sample	Force (kN)	Displacement (mm)
1	47.4	1.5
2	47.4	1.5
3	47.4	1.5

Figure 11. Images of 1<sup>st</sup> and 2<sup>nd</sup> mode shapes of the draglink.

Table 5. Comparison of steering wheel effort and self-centering efficiency between existing and new steering system.

Parameter	Existing Design	New Design
Steering Wheel Effort	1.5 kN	1.1 kN
Self-centering Efficiency	15%	21%

Figure 12. Comparison of steering wheel effort and self-centering efficiency between existing and new steering system.

Figure 13. Comparison of steering wheel effort and self-centering efficiency between existing and new steering system.

Figure 14. Comparison of steering wheel effort and self-centering efficiency between existing and new steering system.

Figure 15. Comparison of steering wheel effort and self-centering efficiency between existing and new steering system.

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Figure 100. Comparison of steering wheel effort and self-centering efficiency between existing and new steering system.

$f$  is the voltage frequency in Hz

$n$  is the rotor speed in revolution per minute

The voltage peak depends of the maximum flux (which is proportional to the current excitation) and the rotor speed

$L$  is the dc current excitation, and  $K_m$  is the constant

Writing  $a$  and  $A$  as identical and can change their function. This is a  $\sin$  wave excitation, and  $a$  can be amplitude. If it is not a  $\sin$  wave excitation, the current will flow in armature coil  $L$ . A current carrying conductor in magnetic field produces a force

The torque on the armature is

Where  $L$  is the rotor mean square current flowing in the armature conductors. In the axial length of the armature wire,  $L$  is the DC field current, and  $K_m$  is the constant coefficient

In the motor mode operation, the armature current must flow in direction of existing armature voltage and have direction opposite to voltage direction. That is why, in the motor mode operation, there is a  $\sin$  wave of a  $\sin$  wave (voltage) position

If the armature current voltage is  $V_a$ , the armature resistance is  $R_a$ , and armature inductive reactance is  $X_a$ , then for a generator mode operation

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