A Study on the Lateral Stiffness of the Passenger Car Suspension

Moonho Yang

Hyundai Motor Company

Abstract: The vehicle handling performance is the main function of vehicle suspension systems for vehicle to be stable during severe cornering and/or abrupt misused steering maneuver conditions. It is essential to satisfy sufficient lateral stiffness of vehicle suspension system for the effective vehicle handling performance as well as avoiding contact problem between brake rotor and other adjacent parts. Accordingly, it is important to make prediction of lateral suspension stiffness with accurate computational simulation model, so that the suspension designer can verify the handling performance before conforming detail suspension parameters.

This paper shows that the lateral stiffness analysis result of vehicle suspension can be improved with the accurate bearing stiffness model correlated with experimental vehicle test data and also, shows which design parameters contribute to lateral stiffness of vehicle suspension.

Keywords: lateral Stiffness, bearing stiffness

1. Introduction

During severe cornering and/or abrupt misused steering maneuver conditions, the axle system can be subjected to the excessive lateral force generated at the tires contact patch. This force results in the hub & bearing deflections, which cause contact problem between brake rotor and other adjacent parts(brake caliper torque member, lower control arm) and negatively effect vehicle handling performance.

In this paper the accurate bearing stiffness model correlated with experimental test is reviewed.

2. Bearing FE model

Figure 1 shows a example of bearing model. The respective bearing balls are modeled using a non-linear SPRINGA element. DCOUP3D element is used to represent the contact area of a bearing ball.

Figure 2 shows a layout example of the axle system with 1'st generation bearing. In case of 1'st generation bearing, SHRINK FIT and PRETENSION are used to represent interference fittings of the bearings on the hub and on the knuckle by negative tolerance and the tightening nut respectively. And SHRINK FIT is used to represent interference fitting by orbital forming of the 3'rd generation bearing. Figure 3 shows a layout example of the 3'rd generation bearing.
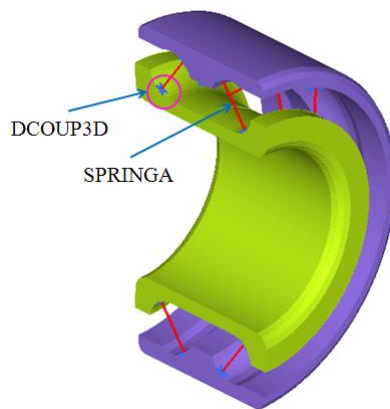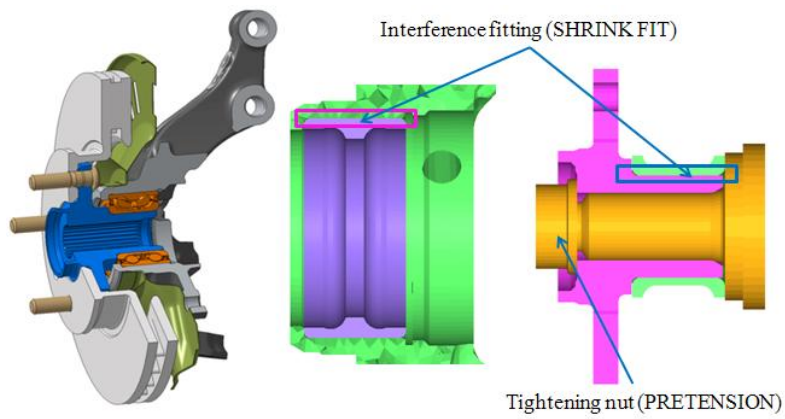
Figure 1. Bearing FE model

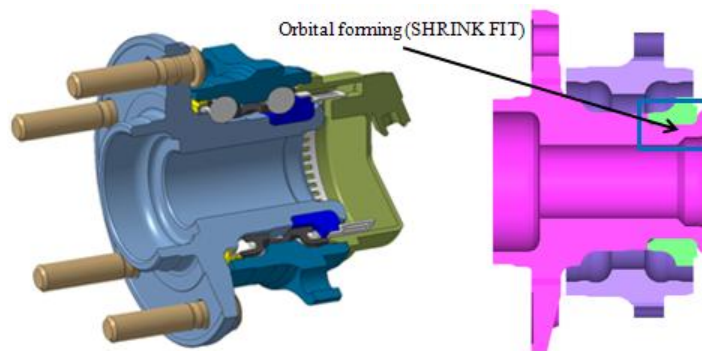Figure 2. Axle system with 1'st generation bearing

Figure 3. 3'rd generation bearing

3. Axle system stiffness

3.1 Test and analysis of the axle system stiffness

Figure 4, 5 show the test device and FE model of the axle system to correlate the axle system stiffness.
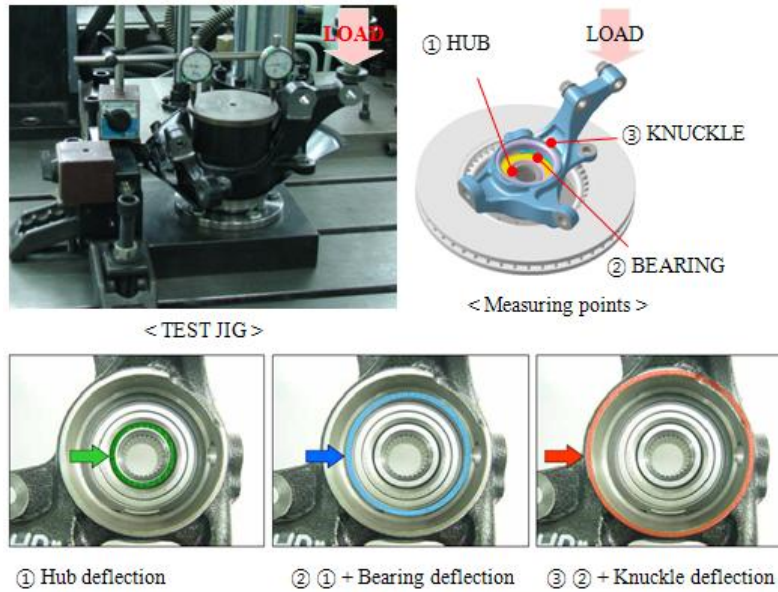

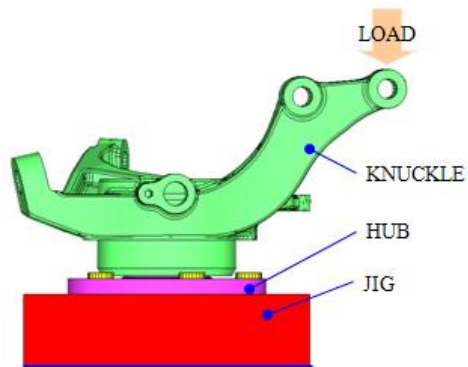Figure 4. Axle system stiffness test

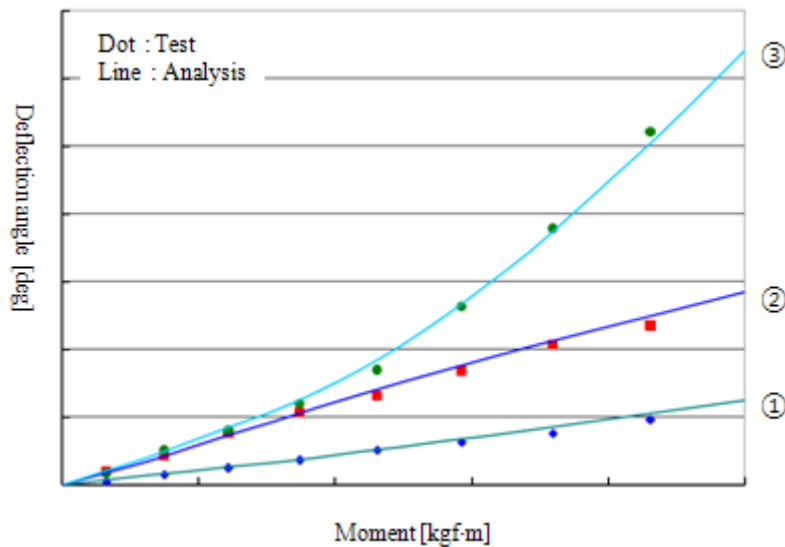Figure 5. FE model for the axle system stiffness analysis

Figure 6. Test and analysis result of axle system stiffness

Figure 6 shows the test and analysis result of A-vehicle axle system stiffness. Compared to the test data, the analysis result has good accuracy. The bearing defection to the axle system stiffness is about 2 times more than the hub deflection. The non-linearity of knuckle deflection curve is due to sliding between knuckle and bearing outer race.

3.2   Parameter study of the axle system stiffness

Using this bearing stiffness model, the axle stiffness analyses of several design variables are conducted. Figure 7 show design variables.
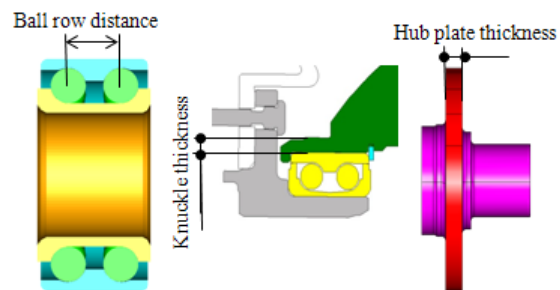

Figure 7. design variables

Table 1. analysis result of design variables (at 0.6G load)

Ball distance	Knuckle thickness	Hub plate thickness	Deflection angle
present	present	present	1.0
present + 2mm	present	present	0.959
present	present + 1.5mm	present	0.957
present	present	present - 2mm	1.045

Table 1 shows that ball distance, knuckle thickness and hub plate thickness play an important role in the axle system stiffness.

4. Full suspension system stiffness

4.1 Test and analysis of the full suspension system stiffness

Figure 8, 9 show SPMD(suspension parameter measuring device) and the full FE model of the suspension system including BIW and flexible tire FE model.

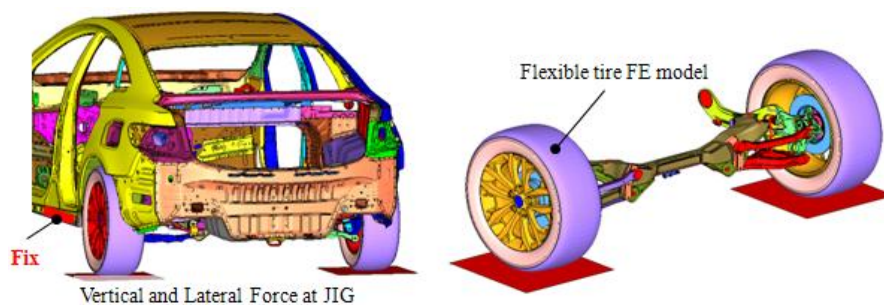Figure 8. SPMD (suspension parameter measuring device)

Figure 9. full FE model of the suspension system

Table 2 shows the test and analysis result of the full suspension system stiffness. Compared to the test data, the analysis result has good accuracy.

Table 2. Test and analysis result of the full suspension system stiffness

		Aiding direction	Opposing direction
Vehicle-B	Test	1.0	1.0
	Analysis	1.022	1.023
Vehicle-C	Test	1.0	1.0
	Analysis	0.969	0.974
Vehicle-E	Test	1.0	1.0
	Analysis	0.984	1.028

4.2   Lateral stiffness contribution of the full suspension system stiffness

Using vehicle-F, G model, the lateral stiffness contribution simulations of the suspension design parameters are conducted. The contribution is the increase rate of the lateral stiffness when components are substituted with rigid elements and bushes are substituted with ball joints. Figure 10 shows that lower/upper arm bushes and hub&bearing play a role in the lateral stiffness.
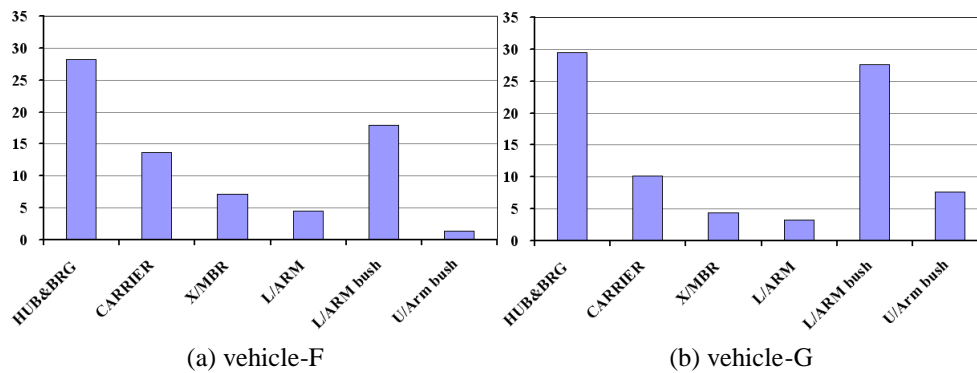

(a) vehicle-F   (b) vehicle-G

Figure 10. An example of the lateral stiffness contribution in a RR suspension system

5. Conclusion

This paper shows that the lateral stiffness analysis result of vehicle suspension can be improved with the accurate bearing stiffness model correlated with experimental test data and also, shows which design parameters contribute to lateral stiffness of vehicle suspension.

6. References

1. Steven J. Weber, "Eliminating Caliper Piston Knock Back In High Performance Vehicles", SAE, 2006-01-3197.

2. Gianini C., "Formula One Car Wheel Bearings: an FE Approach", ACC 2007