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Research on Optimization Method of Vehicle Performance Based on Experiment Design

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Abstract. Aiming to some problems of the domestic car of handling and stability and ride comfort, for example： lateral response lag ,too big dead zone and small steering wheel force feeling of on center handling performance, large longitudinal and vertical weighted acceleration root-mean-square value in the ride performance with random input. in the design verification stage., the vehicle dynamic model based on the structure is built in ADAMS/Car. In order to achieve the inherent properties of set values during the development stage, we choose the bushing stiffness, the stiffness of the spring, the damper as the main optimization of parameters, using the experimental design method to comprehensive scientific analysis and obtain the optimized scheme, and then carries on the simulation to set the target.

Keywords: Vehicle engineering, Handling and stability, Ride comfort, Design of experiment, Optimization

1. Introduction

Automotive product development capability is the enterprise's core competitiveness, while the domestic most vehicle manufacturers still using traditional physical prototype test iteration method for vehicle development, which will lead to a long development cycle, high cost, high risk. And the world famous automobile manufacturers invested large amounts of funds, using virtual prototype to build automotive digital platform in design validation stage from the age of 80. More began to explore using virtual prototype technology in the product definition and evaluation stages in the recent ten years [1], further shorten the development cycle [2].

Some domestic car is verified by experiment in design validation stage, and the result is comparied with the target value which is setted during the pre development phase. Handling stability and ride comfort of objective evaluation of certain indicators of gap. In order to achieve the set goals, the dynamic mode based on the structure is established in ADAMS / Car and detailed verified. Taking more than the recommended range of objective evaluation index value as the optimization objective, considering the influence of each elastic element except the design parameters[3-4], using experimental design method [5] to carry on the analysis, We propose an optimization scheme, and at last, The handling stability and ride comfort is simulated and validated, its objective evaluation indexs are all in the set range.

2. Objective Evaluation Index Difference

From the physical test data,we derive the objective evaluation index of this car, and contrast with the target value which we set, and the largest differences are shown in table 1.

Tab.1 index contrast

Index	Experimental value	Recommended value
Yaw rate response time(s)	0.178	⩽0.140
Steering wheel torque gradient when	1.591	[2.100,2.500]

lateral acceleration is 0g(Ns2)		
Steering wheel torque dead(Nm)	2.658	≤2.400
X to 80km/h the root-mean-square value of weighted acceleration(m/s2)	0.214	≤0.190
Z to 80km/h the root-mean-square value of weighted acceleration(m/s2)	0.398	≤0.380

We can see the following several main problems:

Lateral response lag-----generally used yaw rate response time,which negotiated as 100km / h, 0.2g in the step angle condition, response time that yaw rate corresponding to the steering wheel angle . Index smaller, the response lag smaller,and the performance better.

Central area of torque dead larger----- negotiated as 100km / h, 0.2g in center area condition, the dead zone width in the longitudinal axis in the steering wheel torque on the lateral acceleration curve ,represent Kulun dry friction in the steering system, should not be too large.

Steering wheel force feeling small----- negotiated as 100km / h, 0.2g in center area condition, 0g steering wheel torque on the lateral acceleration instantaneous gradient, Should not be too large or too small.

Ride random input, X, Z weighted acceleration root-mean-square value slightly larger----- negotiated as X,Z to 80km/h(B road) the root-mean-square value of weighted acceleration, the smaller, the better.

3. Influence of Objective Index

In view of the above problems, we take the bushing stiffness 、 spring stiffness,、 shock absorber damping and so on as optimization parameters.Because of the many influence factors and optimization target values can not read in ADAMS postprocessor directly, so we selecte the major influence parameters as the optimization object, using experimental design method to derive the optimal solution.

The main influence factors of lateral response are analyzed below , bushing stiffness changes in the range of 10%, 20%, 50%, 100%, lateral responses are seen in Fig.1.Do the same way the main influence factors of X to 80km/h the root-mean-square value of weighted acceleration are seen in Fig.2.

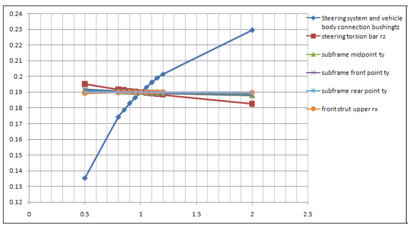

Fig.1 Lateral response time

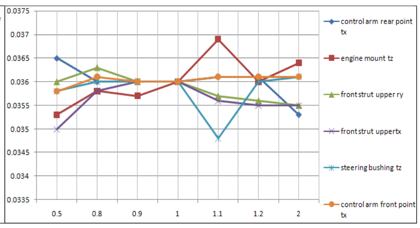

Fig.2 Steering wheel torque

From the above fig we can see some regularities: effect on response time most notably is the Z stiffness of steering and vehicle body connection bushing, second is the torsion bar; response time with bushing stiffness changes linearly; the response time and the steering system and vehicle body connection bushing Z stiffness changes in the same direction, the rest opposite. While the ride random input, nonlinear changes, the rules is not too obvious.

Through the analysis of the influence of single performance index, we select the steering system and vehicle body connection bushing Z stiffness、the stiffness of torsion bar、subframe front and middle point bushing Y stiffness as the optimization parameters; 10%, 20%, 30%, 50% change as a parameter level; Target values are lateral response lag, X、Z to the root-mean-square value of weighted acceleration. We choose $L_{16}4^5$ orthogonal experimental design method as table. 2. Finally using the integrated balance method to select scheme.

Tab.2 test list

factors / number	**Steering Z**	**Torsion bar**	**Sub front**	**Sub middle**
1	10%	10%	10%	10%
2	10%	20%	20%	20%

3	10%	30%	30%	30%
4	10%	50%	50%	50%
5	20%	10%	20%	30%
6	20%	20%	10%	50%
7	20%	30%	50%	10%
8	20%	50%	30%	20%
9	30%	10%	30%	50%
10	30%	20%	50%	30%
11	30%	30%	10%	20%
12	30%	50%	20%	10%
13	50%	10%	50%	20%
14	50%	20%	30%	10%
15	50%	30%	20%	50%
16	50%	50%	10%	30%

4. Optimization and Simulation

Specific optimization scheme:Z direction to the stiffness of bushing steering system and vehicle body connect is decreased by 50 percent; Steering torque rod rigidity increased 20 percent;Y direction to the stiffness of subframe midpoint bushing increased 30 percent; Y direction to the stiffness of subframe front point bushing increased 30 percent; Steering dry friction amplitude decreased 30 percent.

According to the scheme above, the improvement of response time we can see from the step angle condition. 100km / h, lateral acceleration 0.2g, turn left, comparision of lateral accelerations are shown in Fig.4,origin means before modification,final means after modification.

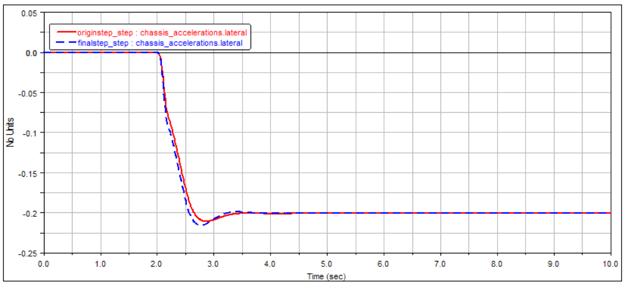

Fig.4 Lateral acceleration

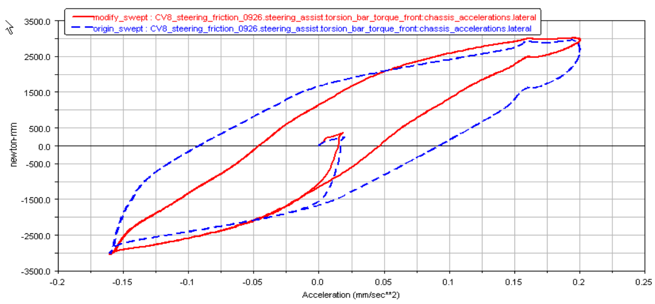

Fig.5 Steering wheel torque

Steering wheel force sense and dead zone we can see from the center zone condition . 100km / h, lateral acceleration 0.2g,the frequency of 0.2HZ, comparision of steering wheel torque are shown in Fig.5 above.

We can see that the performance has been improved,the specific change will seen in table 3.

Tab.3 performance index contrast

Performance index	origin	After optimization	Target value	Optimization percentage

Yaw rate response time(s)	0.1899	0.14	≤0.140	26.28
Yaw rate steady gain(1/s)	0.311	0.26	[0.24, 0.38]	16.4
2.0HZ yaw rate phase lag(deg)	76.35	72.43	≤75	5.13
Linear zone understeering gradient(deg/(m/s2))	0.172	0.2256	[0.018,0.3]	31.16
Steering wheel torque gradient when lateral acceleration is 0g(Ns2)	1.612	2.231	[2.10, 2.5]	38.4
X to 80km/h the root-mean-square value of weighted acceleration(m/s2)	0.036	0.029		19.44
Z to 80km/h the root-mean-square value of weighted acceleration(m/s2)	0.4005	0.352		12.11

According to the above table, When the target performance optimized, the other indicators are still in the initial setting range.

5. Conclusion

In the design verification stage, the vehicle dynamic detailed verification model based on the structure is built. aiming to some problems of Inconsistent performance , use the experimental design method to comprehensive scientific analysis and then put forward a proposal.

The vehicle handling stability and ride comfort test is conducted, target performance is optimizated, meanwhile , the other indicators are still in the initial setting range.

In the actual process of optimization, We not only consider the influence above, but also consider the influence of the initial orientation angle and tire characteristics. Because we do not consider the exchange effect, so this article does not discuss.

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