Optimal Design and Analysis of Intelligent Vehicle Suspension System Based on ADAMS and Artificial Intelligence Algorithms

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Abstract. A complete suspension model is established, and the suspension system is simulated and optimized. The method of suspension system establishment and simulation is explained in detail, and the influence of suspension parameter changes on vehicle handling and stability is analyzed in detail. The dynamic simulation analysis of wheel parallel runout test was carried out on the system, and the suspension system was optimized by artificial intelligence algorithm. The research results provide a technical basis for the design of automobile suspension.

Keywords: ADAMS/Car, Artificial Intelligence Algorithm, Automobile Suspension, Wheel Bounce, Optimal Design

1. Introduction
Suspension dynamics analysis studies the change characteristics of suspension-related performance indicators such as wheel alignment and body pitch caused by the relative movement of the car body and the wheel. Therefore, the essence of the research and evaluation of the suspension kinematics method is to give the suspension. The system inputs a movement, and conducts research and evaluation on the kinematic output characteristics of various suspensions \cite{1-2}. Due to the development of virtual prototype technology, the simulation of the system directly through mature software will greatly improve work efficiency \cite{3-4}. If the suspension design is unreasonable, shimmy phenomenon will occur when the car is driving, which will make the steering stability of the car worse, increase the dynamic load of related parts, reduce its service life, and reduce the reliability of car safety \cite{5-6}. Macpherson type suspension system is very common in today's cars and has a strong representative \cite{7-8}. In view of this, in order to explore the various optimization factors that affect its performance, this article mainly uses a certain A-class car front suspension system as a prototype, and based on computer simulation technology, the virtual simulation prototype software ADAMS/CAR is used to simulate the car suspension system Analysis and optimization.

Artificial intelligence algorithm is a kind of random search algorithm developed based on the natural selection and evolution mechanism of the biological world. It has good convergence and multi-objective optimization. Based on ADAMS/Car, a simulation model of a vehicle's front suspension system was established, and its dynamic simulation analysis was carried out. The artificial intelligence algorithm was used to optimize the vehicle's suspension.
2. Establishment of simulation model of front suspension system

Based on an A-class car as a prototype, referring to the MacPherson independent suspension template and standard suspension test bench in ADAMS/Car, a front suspension system model is established. The automobile suspension is composed of a body, a lower swing arm, a steering knuckle assembly, a steering rod, a shock absorber, a coil spring and a wheel. In the process of modeling, some reasonable simplifications were made to the model, such as ignoring the thickness of the wheel and the elastic effect of various parts. The key to determining the design variables of an automobile suspension model is to determine the hard points. The hard point is an important geometric positioning point of the connection between the parts in the suspension model. The geometric position of the connection point between the parts is given in the coordinate system of the subsystem to determine the hard point. According to the absolute coordinate system, the coordinate value of the hard point can be obtained from the design drawing. The absolute coordinates of the hard points on the left half of the suspension are shown in Table 1. ADAMS/Car will automatically create symmetrical hard points and parts relative to the longitudinal centerline.

| Hard point                              | x/mm  | y/mm  | z/mm  |
|-----------------------------------------|-------|-------|-------|
| Drive shaft input breakpoint            | 0.0   | -200.0| 425.0 |
| Front connection point F of lower arm   | -200.0| -450.0| 350.0 |
| Lower arm outer connection point E      | 0.0   | -750.0| 350.0 |
| Rear connecting point G of lower arm    | 200.0 | -450.0| 350.0 |
| Spiral spring base fulcrum              | 40.0  | -650.0| 800.0 |
| Lower connection point B of the lower body of the shock absorber | 40.0 | -650.0| 800.0 |
| Front fulcrum of subframe               | -400.0| -450.0| 350.0 |
| Rear fulcrum of subframe                | 400.0 | -450.0| 350.0 |
| Steering trapezoidal breakpoint H       | 200.0 | -400.0| 500.0 |
| Knuckle connection point C               | 150.0 | -750.0| 500.0 |
| Suspension upper fulcrum A              | 57.5  | -603.8| 1000.0|
| Wheel center D                          | 0.0   | -800.0| 500.0 |

3. Simulation and optimization analysis of automobile suspension

3.1. Artificial intelligence algorithm

Artificial intelligence algorithm (AIA) is a kind of randomized search method that draws on the evolutionary laws of the biological world (survival of the fittest, survival of the fittest genetic mechanism). Its main feature is to directly operate on structural objects and does not exist. The derivation and the limitation of function continuity; it has inherent implicit parallelism and better global optimization capabilities; using probabilistic optimization methods, it can automatically obtain and guide the optimized search space, and adaptively adjust the search direction. Need to determine the rules. These properties of artificial intelligence algorithms have been widely used in fields such as combinatorial optimization, machine learning, signal processing and artificial life.

In artificial intelligence algorithms, the solution of the optimization problem is called an individual, expressed as a parameter list, called a chromosome or gene string, and is generally expressed as a simple string or number string. At the beginning of the algorithm, a certain number of individuals are randomly generated. The operator can also intervene in this random generation process and sow the partially optimized seeds. In each generation, each individual is evaluated, and a fitness value is obtained by calculating the fitness function. The individuals in the population are sorted according to their fitness, with the highest fitness in the front. The analysis process is shown in Figure 3.

Extend the framework by adding vectors representing structural optimization. Therefore, the state vector in the smart algorithm is written as:
\[
x = [x^T_p, x^T_l, x^T_i]^T
\]

(1)

Points and structural optimization elements are all represented by inverse depth parameterization \((m_i \in \mathbb{R}^{6 \times l} \text{ and } l_i \in \mathbb{R}^{4 \times l})\). The estimation uncertainty is described by the covariance matrix.

\[
\Sigma = \begin{bmatrix}
\Sigma_{ic} & \Sigma_{ip} & \Sigma_{il} \\
\Sigma_{pi} & \Sigma_{pp} & \Sigma_{pl} \\
\Sigma_{li} & \Sigma_{lp} & \Sigma_{ll}
\end{bmatrix}
\]

(2)

The diagonal block matrix is the covariance of the camera, point feature and structure optimization feature. The rest of the block matrix is the cross variance between different variables.

### 3.2. Simulation analysis of automobile suspension

The calculation of various motion characteristic parameters of the suspension system is obtained through the geometric analysis and flexibility matrix analysis of the suspension. Among them, geometric analysis refers to the changes in the position and direction of various objects in the suspension steering system under various motion inputs such as suspension jump, roll, and steering system steering. Many vehicle parameters are calculated by geometry. The analysis was carried out.

In the geometric analysis of the suspension, the main parameters are the kingpin inclination angle (the angle between the kingpin axis and the vertical axis in the front view of the car body), the kingpin caster angle (the angle between the kingpin axis and the vertical axis in the top view of the car body), and the outside of the wheel. Inclination angle (the angle between the center plane of the wheel and the vertical plane of the vehicle center) and the toe angle of the wheel (the angle at which the wheels on the left and right sides of the vehicle body are inclined inward), etc. The parallel run-out test method of left and right wheels is the basic method for the analysis of suspension motion characteristics. In fact, it is the suspension motion caused by the suspension movement when the wheel encounters obstacles, the bumpy movement caused by the uneven road, and the suspension movement caused by the body trim during the acceleration and deceleration of the car. Comprehensive analysis of more movement such as suspension movement caused by body roll.

The simulation analysis of the parallel run-out test of the left and right wheels is an important basis for analyzing the rationality of the suspension movement, which more comprehensively reflects the suspension movement characteristics. The kinematics simulation of the double-wishbone independent suspension when the wheels on both sides jump vertically up and down is performed on the suspension test bench. The wheels start from the static equilibrium position and the up and down jump range is \([-100\text{mm}, 100\text{mm}]\). One of the parameters of the right wheel can explain the problem, so this article only uses the positioning parameters of the left wheel. The relevant parameters of the suspension system geometric analysis change with the wheel beating stroke. Through the dynamic simulation of the established front suspension steering system model, the simulation step number is set to 15, and the analysis result curve is obtained in the AD-AMS/Postprecessor module. That is, the geometric analysis of the related parameters (king pin inclination angle, king pin caster angle, wheel camber angle, wheel toe angle) changes curve with the wheel heartbeat.

### 3.3. Optimization analysis of automobile suspension

In order to solve the problems in the suspension model built, the structure adjustment of the front suspension is considered. Using Matlab programming, when the wheel bounces up and down relative to the car body, the weighted sum of the absolute value of the wheel camber angle and the wheel toe angle relative to the balance position is the fitness evaluation function, and the suspension upper fulerum is shown in Figure 1. A. The hard point coordinates of the turning trapezoidal breakpoint H
and the midpoint J of the center axis of the lower swing arm are designed variables to perform 120 generations of genetic optimization operations to obtain the optimized chromosomes, that is, the optimized hard point coordinates. In this paper, the crossover rate of chromosomes in each generation is $P_c=0.3$, and the mutation rate $P_m=0.1$. The optimization results are shown in Figure 1 and Figure 2, and the hard point coordinates before and after optimization are shown in Table 2.

![Figure 1. Comparison of front and rear wheel camber angles after optimization](image1.png)

![Figure 2. Optimized front and rear wheel toe angle comparison](image2.png)

| Hard point                  | x/mm Before optimization | x/mm Optimized | y/mm Before optimization | y/mm Optimized | z/mm Before optimization | z/mm Optimized |
|----------------------------|--------------------------|----------------|--------------------------|----------------|--------------------------|----------------|
| Suspension upper fulcrum A | 57.5                     | 56.3           | -603.8                   | -626.8         | 1000.0                   | 1016.4         |
| Steering trapezoidal breakpoint H | 200.0                 | 202.7          | -400.0                   | -403.2         | 500.0                    | 511.9          |
| Center point of lower arm center axis J | 0.0               | 0.0            | -600.0                   | -598.1         | 350.0                    | 353.6          |

From the analysis of Fig. 1 and Fig. 2, it can be seen that the variation range of wheel camber angle is reduced by 50% after optimization, and the variation range of wheel toe angle is reduced by 26% after optimization. This is beneficial for preventing the deterioration of the straight-line driving stability caused by the left and right braking force errors during braking and reducing the lateral force of the ground on the tires caused by the camber angle to cause the car to deviate, and it is beneficial to reduce the wear of the tires. It is also advantageous.

4. Conclusion

In this paper, a virtual test platform of the front Macpherson independent suspension of a certain car is established in ADAMS/Car. On the basis of this test platform, the kinematics simulation analysis of the front suspension system is carried out, that is, the simulation analysis of the parallel run-out test of the left and right wheels. And use artificial intelligence algorithms to perform multiple genetic optimization operations on the hard point coordinates of the model, which optimizes the positioning parameters and performance indicators of the model, and improves the straight stability of the car, the
ease of steering, the under-steer characteristics when turning, and the reduction of tires. The wear and tear of the car is beneficial, and can be used as a reference for the design of automobile suspension.

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