Scholar Publishing Group
Kinetic Mechanical Engineering
https://doi.org/10.38007/KME.2023.040105
ISSN 2790-2676 Vol. 4, Issue 1: 40-47

Modeling and Design of Automotive Engine Performance Based on Finite Difference Method

Lakshmi Mayank*

Vrije Universiteit Brussel, Belgium

**corresponding author*

Keywords: Finite Difference Method, Automobile Engine, Performance Modeling, Service Performance

Abstract: With the continuous development of the automobile industry, it has put forward higher requirements for the engine performance. In actual production, the failure of vehicle parts often occurs due to various factors. Especially for some parts with complex structure, they are more likely to fail. Therefore, in order to ensure the safe and reliable driving of vehicles and meet the use needs of vehicle owners and improve vehicle quality, this paper uses the finite difference method to model and analyze the design. Then, based on the finite difference method, this paper designed the automobile engine performance model, and tested the function of the model. The test results showed that the automobile engine performance modeling based on the finite difference method used a special process to coat silicon carbide powder on the inner wall of the cylinder block, which can improve its wear resistance and prolong its service life by 1~2 times. The high-grade refractory materials made of it are heat-resistant, small in size, light in weight and high in strength, Good energy-saving effect.

1. Introduction

The automobile industry is the basic industry of a country, which involves all aspects of people's daily life, including transportation, transportation, manufacturing and other fields. With the development of world economic globalization and China's rapid economic growth [1-2]. China's passenger car ownership continues to rise. At the same time, there are also many problems in traffic safety, such as frequent traffic accidents, traffic congestion seriously affecting urban residents' travel and so on, which has become one of the focuses of social attention [3-4].

In foreign countries, there has been a relatively complete and mature theoretical system for the research of automobile engines. However, this aspect started late in China. At present, there is no relatively complete, systematic, highly practical model or algorithm that has the characteristics of a certain production scale and technical level and can meet the requirements of practical application requirements and performance indicators to solve the problems in reality, but its development is limited due to time constraints and insufficient knowledge reserves in related fields, Foreign automotive engine research has already had a relatively mature theoretical basis and rich experience [5-6]. In China, many scholars have put forward their own views on the intelligent and lightweight design of automobile engines, and achieved some results. Some scholars and others have studied the relationship between vehicle power performance and vehicle performance, and found that the average speed reduction rate of the driver is - 2.5% when idling, while the increase rate of the average speed increase rate is higher with the increase of acceleration time. This shows that the automobile engine has a great impact on the fuel economy at high speed, but due to the large population in China, the number of automobiles is still limited [7-8]. Therefore, based on the finite difference method, this paper models and designs the service performance of automobile engines.

In this paper, the finite difference method is used to build a three-dimensional model of the automobile driving system. Firstly, the vehicle is meshed according to the actual running situation of the vehicle on the road, and then the relationship between the parameters under different working conditions is created and analyzed using SUI6.0. Through solving the equations of motion of each node and the boundary conditions such as torque and speed, the simulation results are obtained and the effectiveness, reliability and feasibility of the optimization design method are verified. Finally, the finite element method is applied to the simplification of the engine model of passenger cars.

2. Discussion on the Modeling of Automotive Engine Performance Based on Finite Difference Method

2.1. Service Performance of Automobile Engine

Under normal driving conditions, the temperature of the vehicle is at a constant value when the engine is running, and then gradually decreases when the vehicle is running at high speed or low speed, at a slow speed or at a fast speed. Therefore, in order to ensure that the vehicle performance indicators meet the design objectives and improve the service life of parts, a comprehensive analysis should be conducted. Because the main research object of this subject is the engine working life and various data of medium passenger vehicles and some heavy trucks (such as light trucks). The working environment of automobile engine requires frequent starting, idling and air exchange under various complex working conditions, which requires us to have good fuel economy. The mutual influence relationship and coordination degree between vehicle parts are very large and difficult to change under different parameter conditions. However, if the best matching state is to be achieved, it is necessary to ensure the mutual coordination between various parts to finally achieve the optimal overall function [9-10]. Therefore, the complex and changeable working environment of automobile engine has high requirements for its components and assembly process. During the use of automobile engine, the vibration caused by the piston head bearing different loads is caused by the change of pressure in the cylinder. The engine output power is maximum when the vehicle body is high. However, the cylinder barrel wall and connecting rod cavity are thin, sharp and uneven, and exist on the convex surface. If the oil pressure is low or the temperature is too high, the internal part of the cylinder will be severely deformed, resulting in thermal stress concentration, which will reduce its service life and even damage machine parts. In serious cases, it will lead to deflagration or incomplete combustion [11-12].

2.2. Vibration Response of Engine

In the process of engine running, due to various mechanical vibration and working environment, a lot of noise will be generated inside the engine. In order to obtain more stable and high-precision engine operating state data to meet the vehicle dynamic performance requirements when driving. Therefore, it is necessary to carry out modal analysis on the research object and establish a finite element model to realize robustness test and transient response calculation and other functions. Using computer simulation and optimization design technology, the actuator damping curve fitting under various working conditions is not considered. The engine vibration is mainly caused by the vibration generated by the combustion of gas in the cylinder. When the cylinder volume and exhaust valve opening remain unchanged, relative motion is formed between the piston and the connecting rod group. At this time, the air column will rotate perpendicular to the axis [13-14]. As this rotating form acts on the cylinder head and drives the seal ring to do axial feed (i.e. intake), the cylinder body shakes. Under the action of crank swing angular acceleration, vibration occurs in the cylinder, and at the same time, noise is caused by the friction torque and gas pressure difference between the outer wall of the combustion chamber and the inner wall of the cylinder. In the process of engine running, due to various complex reasons, its internal vibration will occur. In order to study and analyze the influence of this non-uniformity on the overall performance of the vehicle and the problem of noise attenuation, it has high academic value. However, in actual working conditions, it is necessary to determine the relationship between parameters such as frequency response characteristics (sound pressure), spectrum distribution, frequency range, etc. and each point through tests or experiments. In addition, it is also necessary to consider the vehicle driving conditions, vibration forms and their related components, that is, the resonance and acceleration of the frame when the engine is running. Therefore, finite element analysis software can be used to simulate the engine vibration, which is mainly generated by cylinder head, connecting rod shaft, crank and other components. When we use it, we find that there are various complex parts with different shapes and sizes inside the engine. This kind of problem will lead to the reduction of its working performance and reliability. If it is in such an environment for a long time, it may cause deformation or even fracture failure of parts and components, which will eventually lead to catastrophic accidents. Figure 1 is the vibration response diagram of the overall performance of the automobile engine [15-16].

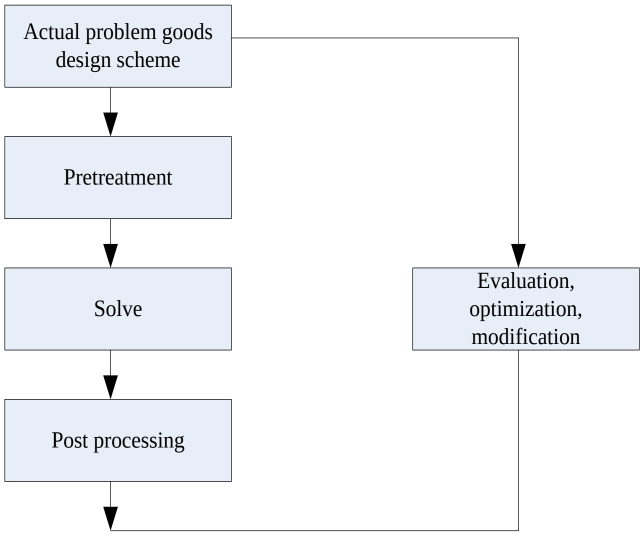

Figure 1. Overall performance vibration response of automobile engine

2.3. Finite Difference Method

The finite difference method is a linear process of solving discrete approximate solutions. Its purpose is to convert a continuous function matrix into a set of random equations, and then obtain the required evaluation by algebraic operation on each line and each element. This method is usually used in practical applications. Figure 2 is the flow chart of the finite difference method.

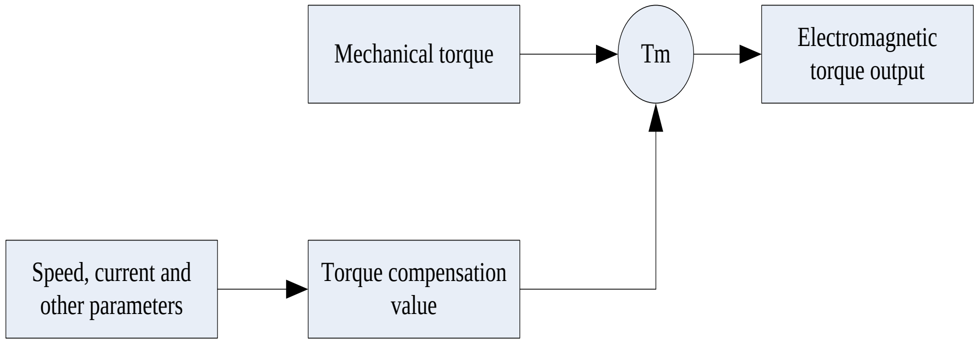

Figure 2. Finite-difference method process

Because the principle of maximum membership degree and the consistency of a priori set with general equations are widely used in the field of engineering analysis, theoretical research and industrial production, the basic idea of the finite difference method is to transform the discrete approximate solution into a directed and unordered system of equations. This method is carried out on a computer, and there is a linear relationship between its input and output, Therefore, it is necessary to export the input set first and then impose corresponding constraints on each output node [17-18]. Then the discrete cosine transform is used to divide the points in the continuous space into several small grid elements. In this way, different forms and parameters can be selected to determine the boundary shape, division size and connection mode of each element, so as to obtain the integrated structural model of the whole system. When solving by the finite difference method on the computer, this method takes the continuous node imbalance as the objective function, establishes a linear equation group, and then solves according to the obtained analytical equation. However, the problem of system analysis with nonuniformity is obtained after discretization. Therefore, it is only applicable to those with relatively small boundary conditions and modal characteristics. First, it is required to assume - a no-load working point bmo, then the air gap flux provided by the permanent magnet when the PMSM is no-load is as follows:

$$\phi_{\delta 0} = \frac{b_{m0} B_r S_m}{\sigma_0} \tag{1}$$

Among them, φ 0 is the air gap magnetic flux at no load, B is the remanence density of the permanent magnet, and S is the sectional area of each pole magnetic flux provided by the permanent magnet σ Is the no-load magnetic leakage coefficient, and the expression of air gap magnetic density of the motor is:

$$B_\delta = \frac{\phi_{\delta 0}}{\alpha_p \tau_p l_{eff}} \tag{2}$$

Where, B is the air gap magnetic density of the motor, ax 'is the pole arc coefficient of the main pole, τ Is the motor pole distance, Ie is the effective length of stator core.

3. Experimental Process of Modeling of Automotive Engine Performance Based on Finite Difference Method

3.1. Modeling of Automobile Engine Performance Based on Finite Difference Method

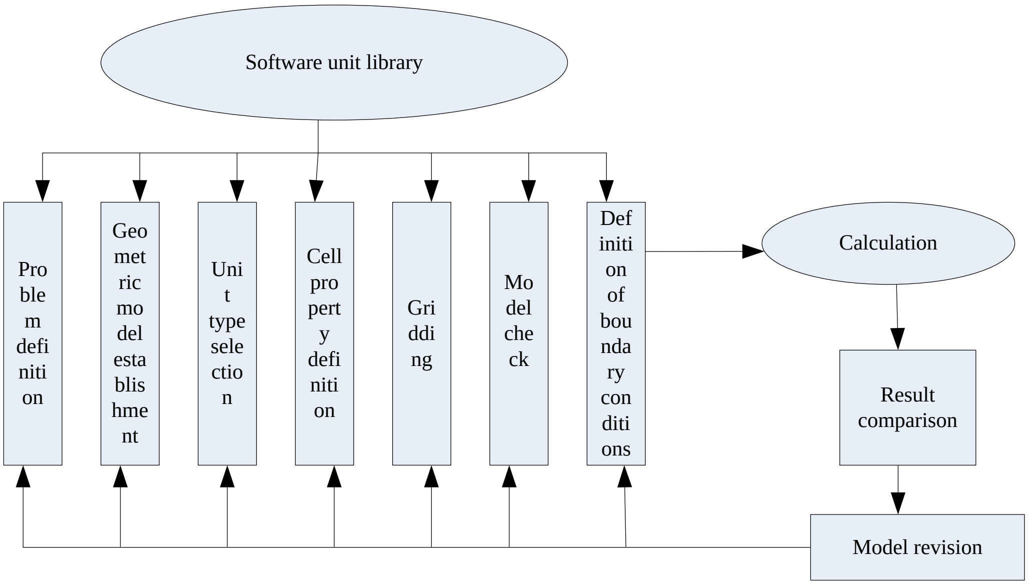

Figure 3. Modeling of automobile engine usage performance based on the Finite Difference method

The performance model of automobile engine based on the finite difference method (as shown in Figure 3) is based on the analysis of various parameters in its working process, and the results are provided to the drive axle, body, frame and other parts. The research object of this paper is the performance of the vehicle when driving and the comfort of the whole vehicle. Therefore, if you want to accurately describe the working conditions of the automobile engine system, you must first determine the required solution problem domain and its boundary conditions, and then select the appropriate method to make appropriate corrections to the objective function and constraint conditions according to the actual situation to obtain the final parameter values that need to be calculated. In the process of engine operation, when the cylinder is filled with a certain amount of oil, a large amount of fine particulate gas will be generated inside. These particles have different diameters, different homogeneity and uniform distribution. Therefore, in order to accurately describe the impact of piston and cylinder barrel parts on vehicle driving performance, it is necessary to carry out analysis and research and experimental testing from the practical point of view to draw reliable conclusions. If the working environment of the automobile engine is harsh and the engine itself is complex and difficult to design and manufacture, then it is necessary to use the finite difference method to establish its model and calculate its parameters.

3.2. Functional Test of Automotive Engine Performance Based on Finite Difference Method

The performance analysis of automobile engine includes all parts and the general layout of the whole vehicle, and these parts are subject to various factors such as temperature, air pressure load and vibration frequency changes in the actual use process. Therefore, it is necessary to accurately model them. In order to ensure that the model can correctly simulate the functional indicators required to be achieved under real working conditions (that is, whether the final output results are consistent with the calculated conclusions) and the relationship between various parameters, that is, the interaction and coupling between the performance indicators of various parts and their geometric dimensions, etc., and to verify the rationality and reliability of this model in engineering, If the result is correct, it indicates that the simulation method can meet the design requirements. Otherwise, if the result is wrong due to improper handling in the case of failure or failure, the system can be used again to solve the problem.

4. Experimental Analysis of Automotive Engine Performance Based on Finite Difference Method

4.1. Functional Test Analysis of Automotive Engine Performance Based on Finite Difference Method

Table 1 shows the functional test data of automobile engine performance modeling.

Table 1. Automotive engine use performance modeling function test

Test times	Air pressure load	Frequency of vibration	Modulus of elasticity
1	563	273	773
2	672	534	675
3	656	563	673
4	562	356	535
5	726	235	463

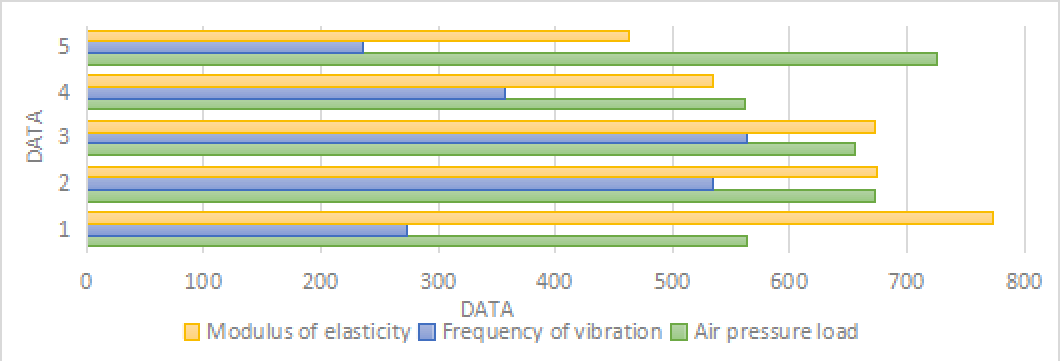

Figure 4. Car engine use performance modeling

Through the simulation and analysis of the working state of the automobile engine in the running process, it is found that the automobile engine will produce various complex structures such as cylinders, pistons and cylinder heads under different working conditions and different speeds. Therefore, in order to study whether the environmental parameters (such as temperature, pressure distribution uniformity, etc.) of the cylinder block and cylinder wall meet the design requirements when the vehicle is running, it is necessary to establish a test function module based on the finite difference method software to simulate and analyze its dynamic characteristics, so as to verify the practical value of the test method. It can be seen from Figure 4 that the modeling of automobile engine service performance based on the finite difference method uses a special process to coat silicon carbide powder on the inner wall of the cylinder block, which can improve its wear resistance and prolong its service life by 1~2 times. The high-grade refractory made of silicon carbide powder is characterized by heat shock resistance, small size, light weight, high strength and good energy saving effect.

5. Conclusion

In this paper, the automobile engine is taken as the research object, and the automobile power model based on the finite difference method is established. Aiming at the problems of complex engine working environment and high noise, the engine is applied to the simulation analysis of many varieties of low-speed power vehicles. According to different vehicle types and performance requirements, it is modeled and optimized design methods are proposed. SPSCAD/ANVEVM software is used to complete the 3D entity assembly, mesh generation and discretization processing to achieve the geometric dimension solution of each component. The vehicle model is established using the finite element method.

Funding

This article is not supported by any foundation.

Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] Munseong Bae, Haejun Chung:Modeling Dispersive Media in Finite-Difference Time-Domain Method for Radiative Cooling Applications. IEEE Access 10: 40843-40851 (2022).

[2] K. Aarthika, Ram Shiromani, Shanthi V.:A higher-order finite difference method for two-dimensional singularly perturbed reaction-diffusion with source-term-discontinuous problem. Comput. Math. Appl. 118: 56-73 (2022).

[3] Roberto Rojas, Verónica Sotomayor, Tomohiro Takaki, Kosuke Hayashi, Akio Tomiyama:A phase field-finite difference lattice Boltzmann method for modeling dendritic growth solidification in the presence of melt convection. Comput. Math. Appl. 114: 180-187 (2022).

[4] Ali Hasan Ali, Ahmed Shawki Jaber, Mustafa T. Yaseen, Mohammed Rasheed, Omar Bazighifan, Taher Abdehamed Nofal:A Comparison of Finite Difference and Finite Volume Methods with Numerical Simulations: Burgers Equation Model. Complex. 2022: 9367638:1-9367638:9 (2022).

[5] Maha M. A. Lashin, Muhammad Usman, Muhammad Imran Asjad, Arfan Ali, Fahd Jarad, Taseer Muhammad:Magnetic Field Effect on Heat and Momentum of Fractional Maxwell Nanofluid within a Channel by Power Law Kernel Using Finite Difference Method. Complex. 2022: 3629416:1-3629416:16 (2022).

[6] Ángel García Gómez, Mihaela Negreanu, Francisco Ureña, Antonio Manuel Vargas:Convergence and numerical solution of nonlinear generalized Benjamin-Bona-Mahony-Burgers equation in 2D and 3D via generalized finite difference method. Int. J. Comput. Math. 99(8): 1517-1537 (2022). https://doi.org/10.1080/00207160.2021.1989423

[7] Rakesh Ranjan, Hari Shankar Prasad:A novel exponentially fitted finite difference method for a class of 2nd order singularly perturbed boundary value problems with a simple turning point exhibiting twin boundary layers. J. Ambient Intell. Humaniz. Comput. 13(9): 4207-4221 (2022).

[8] Soner Aydinlik, Ahmet Kiris, Pradip Roul:An effective approach based on Smooth Composite Chebyshev Finite Difference Method and its applications to Bratu-type and higher order Lane-Emden problems. Math. Comput. Simul. 202: 193-205 (2022).
[9] Iraj Fahimi-khalilabad, Safar Irandoust-Pakchin, Somayeh Abdi-Mazraeh:High-order finite difference method based on linear barycentric rational interpolation for Caputo type sub-diffusion equation. Math. Comput. Simul. 199: 60-80 (2022).
[10] Marziyeh Saffarian, Akbar Mohebbi:Finite difference/spectral element method for one and two-dimensional Riesz space fractional advection-dispersion equations. Math. Comput. Simul. 193: 348-370 (2022).
[11] Antonio Manuel Vargas:Finite difference method for solving fractional differential equations at irregular meshes. Math. Comput. Simul. 193: 204-216 (2022).
[12] Geovani Nunes Grapiglia, Max L. N. Gonçalves, G. N. Silva:A cubic regularization of Newton's method with finite difference Hessian approximations. Numer. Algorithms 90(2): 607-630 (2022).
[13] Takahiro Yamaguchi, Tsukasa Mizutani, Kimiro Meguro, Takuichi Hirano:Detecting Subsurface Voids From GPR Images by 3-D Convolutional Neural Network Using 2-D Finite Difference Time Domain Method. IEEE J. Sel. Top. Appl. Earth Obs. Remote. Sens. 15: 3061-3073 (2022).
[14] Rezvan Ghaffari, Farideh Ghoreishi:A Low-Dimensional Compact Finite Difference Method on Graded Meshes for Time-Fractional Diffusion Equations. Comput. Methods Appl. Math. 21(4): 827-840 (2021). https://doi.org/10.1515/cmam-2020-0158
[15] Mehdi Dehghan, Nasim Shafieeabyaneh:Local radial basis function-finite-difference method to simulate some models in the nonlinear wave phenomena: regularized long-wave and extended Fisher-Kolmogorov equations. Eng. Comput. 37(2): 1159-1179 (2021).
[16] Mansour Safarpoor, Ahmad Shirzadi:Numerical investigation based on radial basis function-finite-difference (RBF-FD) method for solving the Stokes-Darcy equations. Eng. Comput. 37(2): 909-920 (2021). https://doi.org/10.1007/s00366-019-00863-5
[17] Betul Hicdurmaz:Finite difference schemes for time-fractional Schrödinger equations via fractional linear multistep method. Int. J. Comput. Math. 98(8): 1561-1573 (2021).
[18] A. M. Kawala, H. K. Abdelaziz:Crank-Nicolson finite difference method for time-fractional coupled KdV equation. Int. J. Comput. Math. 98(12): 2564-2575 (2021).