International Journal of Science and Engineering Applications
Volume 15-Issue 12, 28 – 30, 2026, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1512.1007

Static and Modal Analysis and Research of a Steering Gear Bracket for a Heavy-Duty Truck

Chen Qi
School of Automobiles and Low-Altitude Unmanned Aerial Vehicles
Zibo Polytechnic University
Zibo, Shandong, China

Abstract: This paper uses the Creo software to conduct digital design and modeling for a certain heavy-duty truck steering gear bracket. The Simulate module in Creo is applied to perform finite element modeling for the designed steering gear bracket and conduct static and constrained mode analyses. The static analysis results show that the designed heavy-duty truck power steering gear bracket meets the requirements of strength and stiffness. The modal analysis indicates that the inherent frequency of the heavy-duty truck power steering gear bracket designed in this paper can effectively avoid resonance phenomena when compared with the external excitation frequency. The structure design of the steering gear bracket is reasonable and meets the performance requirements.

Keywords: power steering gear bracket; finite element analysis; modal analysis

1. INTRODUCTION

As one of the important components in the automobile steering system, the power steering gear bracket is located between the vehicle frame and the power steering gear and is rigidly connected to both. Its structural strength and natural frequency directly affect the steering safety and handling stability of the vehicle. As an important component of the steering system, the steering gear bracket has its own natural frequency. If the external excitation is close to its natural frequency, the steering bracket will resonate and the structure will be destroyed [1-2]. Therefore, in order to meet the requirements of NVH in the structural design of the steering gear bracket, the natural frequency of the steering gear bracket needs to avoid the frequency of external excitation as far as possible to avoid vibration. Modal analysis technology is an important step in the dynamic design and analysis of mechanical products at this stage. In this paper, the Simulate module in Creo is used to perform static analysis and constrained modal analysis on the designed heavy-duty truck power steering bracket to obtain the static and dynamic parameters of the power steering bracket. The output of the simulation results provides a strong design guarantee for the structural reliability of the power steering bracket.

2. STATIC ANALYSIS

2.1 Establishment of Three-dimensional Model and Material Properties of Power Steering Bracket

The power steering gear bracket involved in this paper is a frame steering gear bracket designed for a newly developed 4×2 tractor steering system. In Creo software, the model of the new design bracket is established by combining parameterization and entity modeling based on entity features, as shown in Figure 1. The model material is homogeneous and isotropic. In this paper, the material used in the steering gear bracket is QT450-10, and the specific parameters of the material are shown in Table 1.

Table 1 Mechanical properties of materials

Material	Elastic Modulus (MPa)	Yield Strength (MPa)	Poisson Ratio	Density (kg/m^3)
QT450-10	1.73x10^5	310	0.3	7.0x10^3

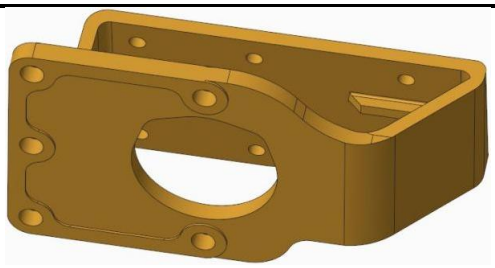


Figure 1 Three-dimensional model of power steering bracket

2.2 The Application of Boundary Conditions and the Division of Finite Element Mesh

The application of boundary conditions includes constraint boundary conditions and load boundary conditions. The power steering bracket involved in this paper is fixed on the side wing surface of the frame through six mounting holes, so fixed constraints are applied to six mounting holes, as shown in Figure 2. The load boundary condition is the force condition of the steering bracket. This paper involves that the steering bracket is mainly affected by the reaction force of its own gravity and its output torque. The reaction of gravity relative to the output torque is much smaller, so it can be ignored. In this paper, the maximum output torque of the power steering gear of the steering system matching the steering gear bracket is 6414 Nm.According to Formula 1, the maximum output torque of the power steering gear is decomposed into the mounting hole of the power steering gear bracket, as shown in Figure 3. The load applied by each mounting hole is shown in Table 2.

$$F_n = T \cdot R_n / \left(R_1^2 + R_2^2 + \cdots + R_n^2\right) \quad (1)$$

International Journal of Science and Engineering Applications
Volume 15-Issue 12, 28 – 30, 2026, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1512.1007

Table 2 Load distribution of each mounting hole

	Mount-ing Hole 1	Mount-ing Hole 2	Mount-ing Hole 3	Mount-ing Hole 4	Mount-ing Hole 5
X	5888N	5888N	0N	-5888N	-5888N
Y	0N	9758N	9758N	9758N	0N

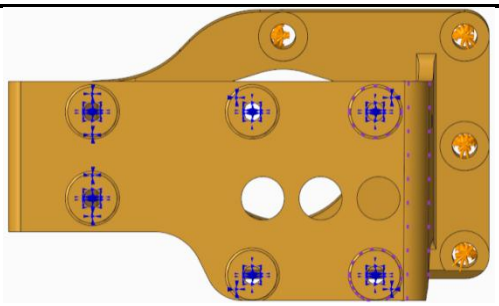


Figure 2 Steering bracket constraint analysis model

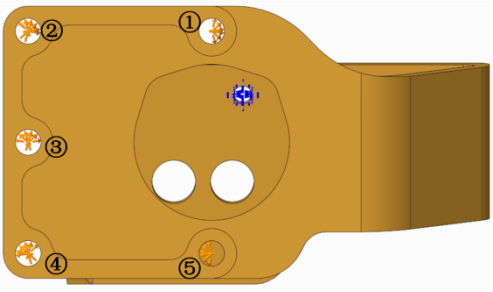


Figure 3 Load analysis model of steering gear bracket

The quality of finite element meshing is related to the accuracy and efficiency of static analysis. According to the previous design experience, as shown in Figure 4, the fillet transition zone at A is prone to stress concentration, which is the area that designers need to focus on. Therefore, the maximum size of the mesh element is artificially controlled at 1mm, and the finite element mesh of the remaining parts is divided by the AUTOGEM function integrated with the Creo / Simulate module [3]. The division result is shown in Figure 4.

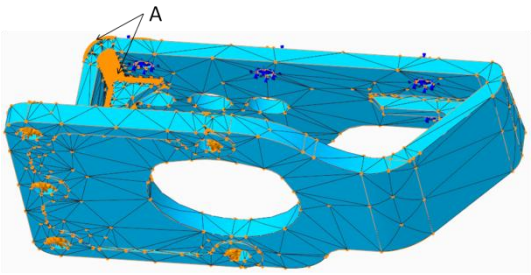


Figure 4 Finite element meshing model of steering bracket

2.3 Analysis of Results

The Creo / Simulate module is used to analyze the statics of the designed heavy truck power steering gear bracket. The simulation results are shown in Figure 5 and Figure 6. From Figure 5, it can be seen that the maximum stress of the steering gear appears in the fillet transition zone, the stress at A is 281.8 MPa, and the stress at B is 260.2 MPa ; it can be seen from Figure 6 that the maximum displacement of the steering bracket appears near the top of the mounting hole 4, and the maximum displacement is 0.3198 mm. Through static analysis, it can be seen that the maximum stress of the heavy truck power steering gear bracket designed in this paper is less than the yield strength of the material, and the maximum deformation is small.

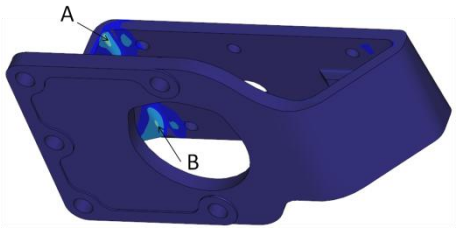


Figure 5 Stress cloud diagram of static analysis of steering gear bracket

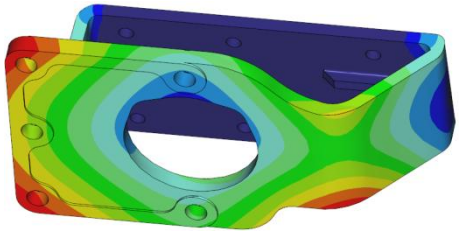


Figure 6 Displacement cloud diagram of static analysis of steering gear bracket

3. MODAL ANALYSIS

3.1 Modal Analysis Process

In the working process of the automobile steering system, the steering bracket is mainly subjected to external excitation such as engine vibration and road excitation when the vehicle is driving on the road with poor road conditions. Therefore, in the design process of the steering gear bracket, it is not enough to only perform static analysis on the bracket. It is necessary to perform modal analysis on the steering gear bracket. Through the structural design, the natural frequency of the steering gear bracket itself avoids the external excitation frequency and avoids structural damage. The modal analysis provides a theoretical basis for the improved design of the structure. Modal analysis is divided into free modal analysis and constrained modal analysis. Constrained modal analysis can better reflect the actual working conditions of the steering gear bracket [4].Therefore, this paper sets the corresponding modal extraction parameters based on the constrained mode to perform modal analysis and calculation on the steering gear bracket.

According to the mechanical vibration equation, the vibration differential equation of the steering gear bracket is :

$$[M]\{\ddot{X}\}+[C]\{\dot{X}\}+[K]\{X\}=\{F\} \quad (2)$$

In the formula : *[M]* is the mass matrix of the steering bracket ; *[C]* is the damping matrix of the steering bracket ; *[K]* is the stiffness matrix of the steering bracket ; *{F}* is the external excitation load vector ; *{X}* is the displacement vector of the steering bracket.

Since the mode is the inherent property of the steering bracket, *[C]* and *{F}* can be ignored, so formula 2 can be transformed into an undamped free vibration differential equation :

$$[M]\{\ddot{X}\}+[K]\{X\}=0 \quad (3)$$

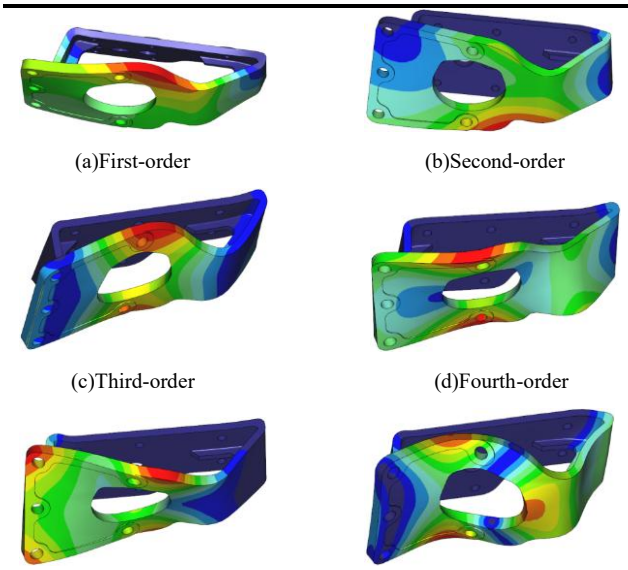
The characteristic equation of Formula 3 is :

$$[K]+\omega^2[M]=0 \quad (4)$$

The natural frequency ωi of the steering bracket can be obtained by solving the square root of the eigenvalue, and then solved by the finite element analysis method. The Creo / Simulate module is used to perform constrained modal analysis on the steering bracket to obtain the natural frequencies of each order of the steering bracket as shown in Table 3 and the vibration modes of each order as shown in Figure 7.

Table 3 The first six natural frequencies of the steering gear bracket

Modal Number	Natural Frequencies(Hz)	Modal Number	Natural Frequencies(Hz)
1	540.699	4	1064.81
2	564.348	5	1216.35
3	758.296	6	1555.77



(a)First-order (b)Second-order

(c)Third-order (d)Fourth-order

(e)Fifth-order (f)Sixth-order

Figure 7 The first six vibration modes of the steering gear bracket

3.2 Analysis of Results

During the driving process of the vehicle, the main external excitation is divided into two categories : First, during the driving process of the vehicle, due to the random excitation of the uneven road surface on the wheel, the imbalance of the wheel is caused[5], and the excitation frequency is about 0~50Hz ; second, the engine idle speed excitation frequency can be obtained from Formula 5:

$$f=\frac{2nz}{60\tau} \quad (5)$$

In the formula : n is the engine speed, r / min ; z is the number of engine cylinders ; τ is the number of engine strokes. For the heavy-duty truck steering bracket designed in this paper, the engine idle speed is 600 r / min, and the engine is 6 cylinders, so the idle speed excitation frequency is 30 Hz ; the maximum engine speed is 2540 r / min, so the maximum rotation frequency is 127 Hz. From the simulation results of Table 3, it can be seen that the natural frequency of the steering bracket is much larger than the external excitation frequency of the vehicle during driving. Therefore, the steering bracket of the heavy truck designed in this paper will not resonate and has sufficient modal stiffness.

4. CONCLUSION

In this paper, the static and constrained modal analysis of the power steering gear bracket designed for a heavy truck is carried out by using the Creo / Simulate module. The static simulation results show that the maximum stress is 281.8 MPa and the maximum displacement is 0.3198 mm, which meet the design requirements of the steering gear bracket. On the basis of static analysis, the constrained modal analysis of the steering gear bracket is carried out again. The simulation results show that the natural frequencies of the steering gear bracket avoid the external excitation and avoid the occurrence of resonance phenomenon, which has practical reference value for the structural design of the subsequent steering gear bracket.

5. REFERENCES

[1] Ding X .Modal Analysis of Automobile Wheels based on Lightweight Technology[J].Journal of Electrical Systems, 2024, 20(3):353-364.DOI:10.52783/jes.2387.

[2] Balasubramanian T , Amirdhavarshini U , Imayavaramban A .Finite Element Analysis in Automobile[J].International Research Journal on Advanced Engineering Hub (IRJAEH), 2025, 3(04):1651-1656.DOI:10.47392/irjaeh.2025.0234.

[3] Liu Y , Gao X , Huang H ,et al.Finite Element Analysis and Optimization of Steering Axle Structure for New Energy Vehicles[J].Symmetry, 2025, 17(11):1882-1882.DOI:10.3390/sym17111882.

[4] Wang Y , Liu Z , Xu F ,et al.Modal Analysis of Assembling Condition for the Air Conditioning Compressor Bracket of a Certain Automobile[C]//2018 International Conference on Robots & Intelligent System (ICRIS).0[2026-11-21].DOI:10.1109/ICRIS.2018.00060.

[5] Lamb M J , Rouillard V .Characterisation of the Rigid Body Vibration Spectra of Road Transport Vehicles[J].Packaging Technology and Science, 2025, 38(1).DOI:10.1002/pts.2852.