

Article

Research on the Design of a Transmission Connecting Plate and Bolt

Jianping Ye

Commodity R & D Institute, Dongfeng Motor Co., Ltd., Wuhan 430057, China; yejianping898@sina.com

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Abstract: The transmission connecting plate is one of the critical components in an engine, serving to connect the engine and the transmission, bearing part of the weight of both the engine and the transmission, and protecting the clutch and flywheel. Given its harsh working environment, the structural design of the transmission connecting plate directly impacts the overall performance of the vehicle. Additionally, the selection of bolts significantly influences the component's strength. This paper focuses on a specific transmission connecting plate, introducing the characteristics of its spatial layout, the placement of mounting positions for the suspension system, material selection, and the establishment of a three-dimensional model. Finite element analysis software is employed to conduct modal and strength analyses of the entire system. Based on the load analysis, potential material strength risks are assessed, and the strength of the bolts is evaluated. Through bench testing, the reliability of this design methodology has been validated.

Keywords: modal analysis; bolt strength; cylinder head; stiffness; die-casting part

1. Introduction

For cars, engine combustion emissions cause the flywheel to rotate, transmitting torque to drive the transmission clutch to work. The transmission connecting plate (hereinafter referred to as the connecting plate) is an important component on the engine, which serves to connect the engine and transmission, bear the weight of the engine and transmission, and protect the clutch and flywheel [1–5].

This component has the characteristics of thin wall, poor rigidity, and the need to install some accessories. It also requires the use of aluminum alloy material to reduce weight. Therefore, sufficient strength and reasonable spatial layout are needed to meet various loads, otherwise there will be a risk of failure [6–10].

This article uses PRO/E 3D modeling software (v8.0) and HyperMesh finite element analysis software (v2017.1) to design a connecting plate. By analyzing the spatial layout characteristics of the connecting plate, combined with assembly process requirements, and based on the bolt installation layout characteristics, ADC12 (Aluminum-Alloy Die Castings 12) material and HT250 (Gray Iron HT250) is used to adapt the design of the parts. CAE (Computer Aided Engineering) analysis is conducted on the modal and strength of the transmission connecting plate system, and risk assessment is carried out on the connecting plate bolts. Installation tests are conducted to obtain sufficient verification. This provides an effective approach for the design and final finalization of the connecting plate, and has certain reference value for the design ideas of engine components [11–14].

2. Establishment of 3D Model of Gearbox Connecting Plate

2.1. Analysis of Spatial Layout Characteristics

The gearbox in this article is located close to the cylinder block, as shown in Figure 1. The spatial distance is only 55.8 mm. Due to space constraints, considering the stress situation of the gearbox, the bolts above the flywheel housing layout should be as dense as possible, and the lower end should be allowed to be relaxed appropriately. The farthest span above the connecting plate bolt (red) is 199 mm, and the farthest distance from the installation hole of the oil pan bolt below is greater than above, as shown in Figure 2. The assembly process requirement for this time is to first install the gearbox connection plate onto the cylinder block, and then install the gearbox. Therefore, it is necessary to design relevant positioning pins and rings to meet assembly requirements.



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The positioning pin is connected to the cylinder block through a connecting plate, and the positioning ring is connected to the gearbox through a connecting plate, while also facilitating the use of bolt installation holes.

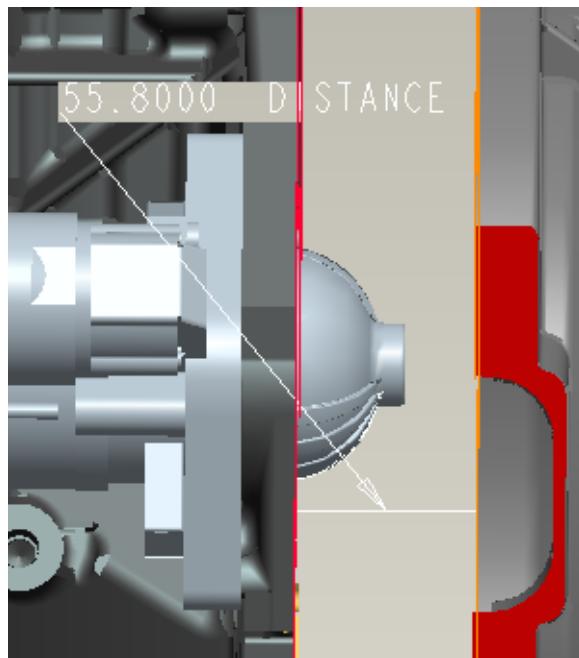


Figure 1. Transmission and cylinder span.

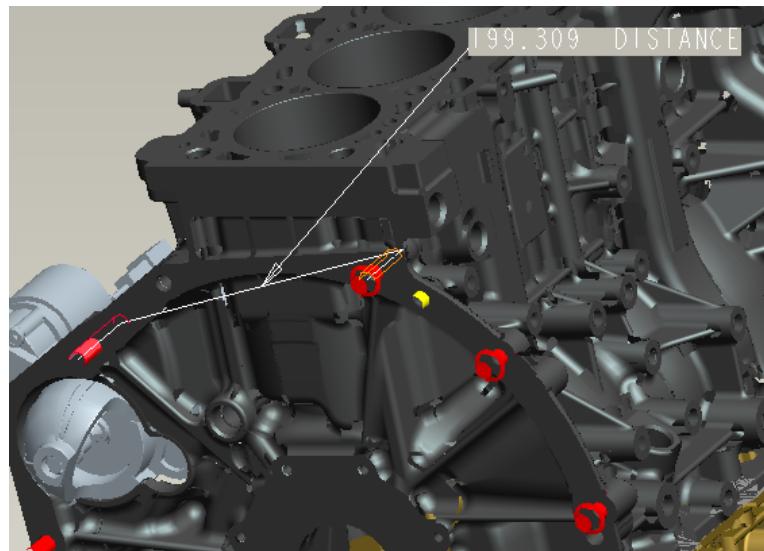


Figure 2. Span of flywheel housing mounting holes.

2.2. Material Selection

Nowadays, engines require lightweighting, and many gearbox connecting plates are made of cast aluminum material, with a density only one-third of commonly used cast iron. The overall weight is reduced, and the dimensional accuracy is also easy to meet. When designing the connecting plate for this development, attention should be paid to matching parts (cylinder block, gearbox, oil pan, etc.) and other materials, as shown in Table 1.

Table 1. Key properties of materials.

Part	Material	Density (kg/m ³)	Modulus of Elasticity (Mpa)	Poisson's Ratio
connection plate	ADC12	2700	70,000	0.33
oil pan	ADC12	2700	70,000	0.33
gearbox	ADC12	2700	70,000	0.33
cylinder block	HT250	7280	138,000	0.156

2.3. Establishment of 3D Model of Connecting Plate

The connection plate needs to be sealed with the cylinder block, oil pan, and gearbox. The thickness of the sealing tape is 10 mm, which can enhance the overall stiffness and strength while minimizing the overall weight. Considering that the surface of the die-casting part is prone to porosity defects, the other parts at the front and rear ends of the sealing tape are hollowed out (yellow areas), as shown in Figures 3 and 4.

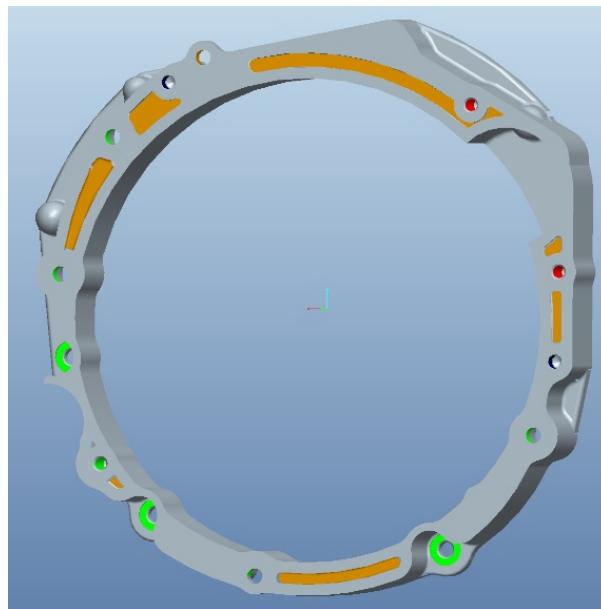


Figure 3. Sealing tape structure.

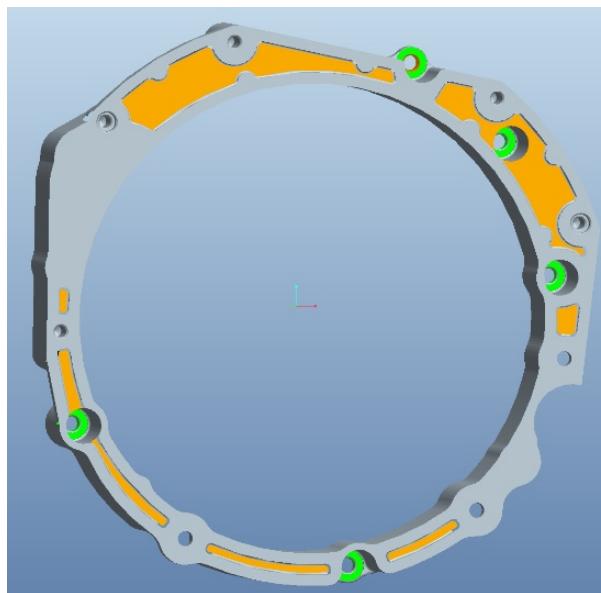


Figure 4. Sealing tape structure.

3. Connection Board Analysis

3.1. Suspension Setting

The transmission connection plate developed this time serves to connect engine cylinder block, oil pan, transmission, starter and other parts, and the engine cylinder block and transmission are fixed by relevant suspensions. Due to spatial layout reasons, the suspension of the cylinder block in this article has been changed to the cylinder head. Therefore, the system analysis needs to consider the cylinder head model in order to be consistent with the real situation and evaluate the overall mode and component strength. Please refer to Figure 5 for details.

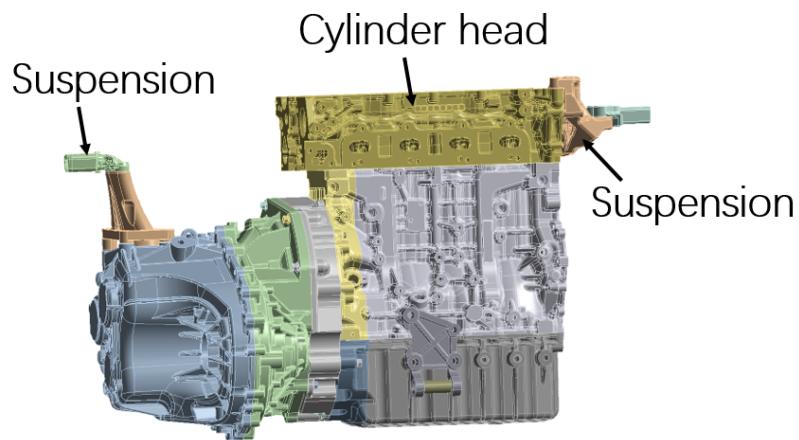


Figure 5. Suspended layout structure.

3.2. Establishment of Finite Element Model

Generate STP format files from the 3D model built in Pro/e, import them into finite element analysis, perform mesh division, and generate tetrahedra. The finite element method, as a numerical analysis method, inevitably has a certain degree of discretization error. The smaller the element size of the connecting plate, the higher its calculation accuracy, but it affects the calculation time. This article recommends grid sizes, as shown in Table 2.

Table 2. Recommended values for finite element mesh size.

Part	Finite Element Mesh Size (mm)
Connection plate	10
cylinder block	45
gearbox	30
oil pan	20
starter	20
.....

3.3. Natural Frequency and Result Analysis

Due to the fact that the dynamic response of a structure often depends on a relatively small number of low order modes, the larger the order, the smaller the impact on the structure. Therefore, only the first 6 frequencies are generally taken for calculation.

The maximum speed of the engine in this calculation is 3600 rpm. The engine used in this calculation belongs to a 4-cylinder engine. Considering a safety factor of 1.2 and a transmission speed ratio of 0.598, the first-order natural frequency of the system (powertrain) should be greater than the resonance frequency required by the engine, which is 120.4 Hz. From the calculation results in Figure 6, it can be seen that the first-order is relatively large, at 211 Hz, and the system meets the requirement of not generating resonance.

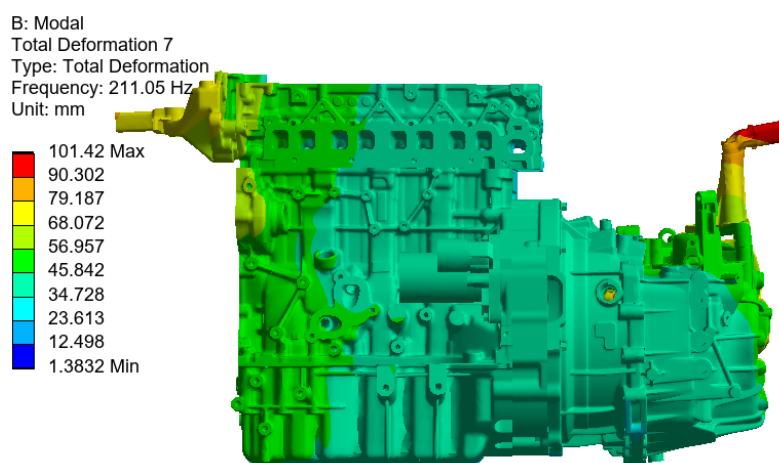


Figure 6. Modal.

3.4. Stress and Result Analysis

Based on past experience, the stress values generated by the fracture of the connecting plate are mainly due to harsh working conditions during the vehicle's operation. The stress generated by bolt installation is relatively small compared to the overall situation, so the stress generated by bolt installation is not considered in this calculation and analysis. The load for this analysis is shown in Table 3.

Table 3. Analyze the load.

Acceleration (G)			
7, 7, 11	-7, 7, 11	7, -7, 11	7, 7, -11

The analysis of the gearbox connecting plate shows that the maximum equivalent stress values do not exceed the yield strength of the material itself, as shown in Table 4. The maximum stress points are located at the root fillet, but there is still a significant distance from the yield strength of the material itself, so it is considered risk-free. As shown in Figure 7.

Table 4. Analysis result.

Working Condition	Calculated Value (Mpa)	Material Yield Strength (Mpa)
7, 7, 11	54.7	
-7, 7, 11	29.5	
7, -7, 11	44.6	147.1
7, 7, -11	24.8	

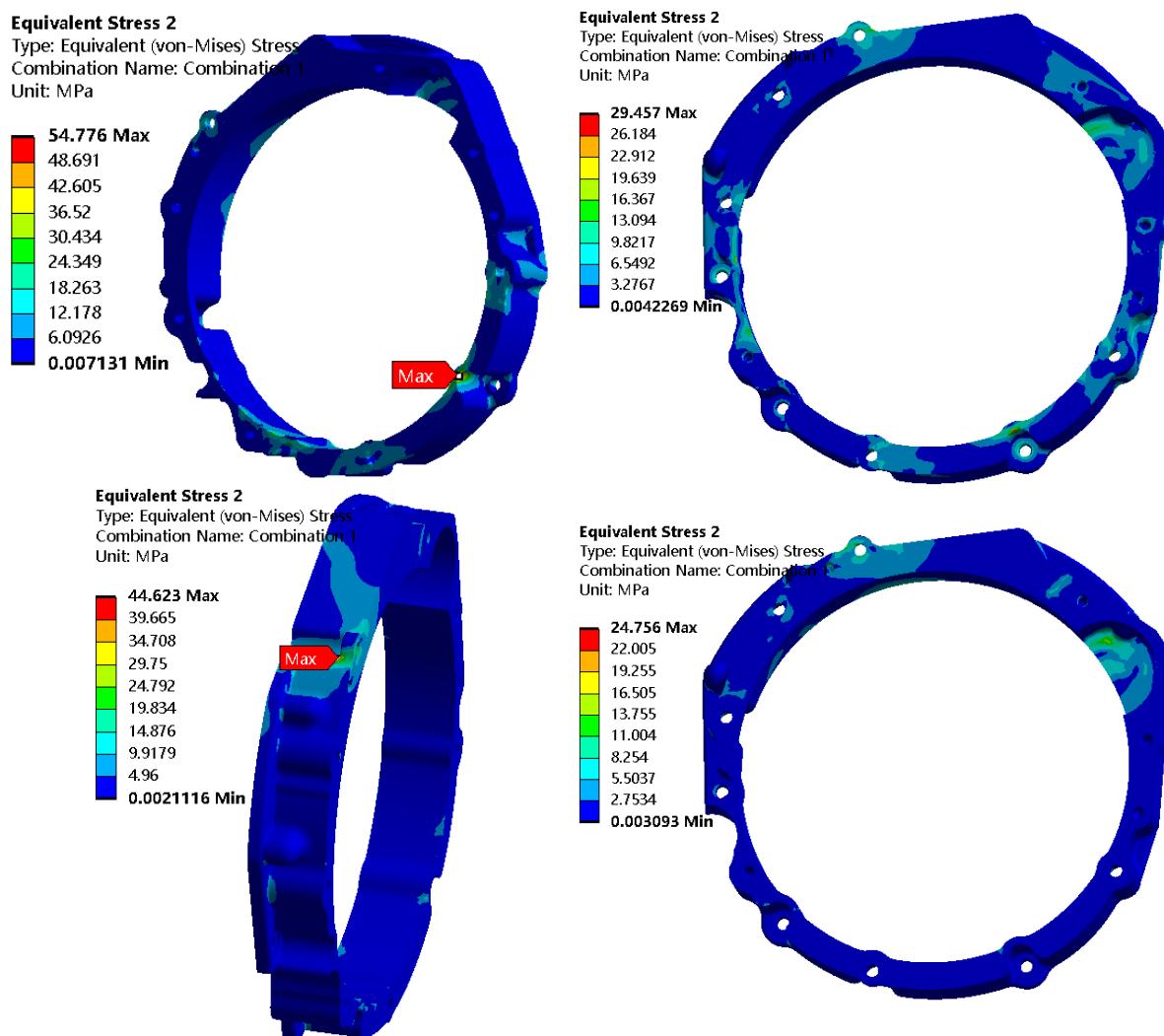


Figure 7. Maximum equivalent stress.

3.5. Bolt Strength Analysis

The distribution of bolts not only affects the strength of the connecting plate, but also has requirements for its own strength. In this article's bolt simulation analysis, beam elements are used instead of bolts to output axial and shear forces. The bolt arrangement structure is shown in Figure 8.

Analysis of bolt strength revealed that the maximum minimum pre tightening force required for bolt 12 is 37,974 N, exceeding the guaranteed load of 33,700 N for grade 8.8 M10 × 1.5 bolts. Please refer to Table 5 for details.

Table 5. Analysis results of bolt No. 12.

Acceleration Load (g)	Axial Force (N)	Shear Force (N)	Minimum Preload Force Requirement (N)
Z + 11 g	-5807.7	3239.4	37,974
Z - 11 g	4657.6	2590.9	30,407
X + 7 g	-156.7	1342.7	9393
X - 7 g	154.2	1344.8	9400
Y + 7 g	2710.1	1583.1	18,196
Y - 7 g	-2712.1	1585.1	18,215

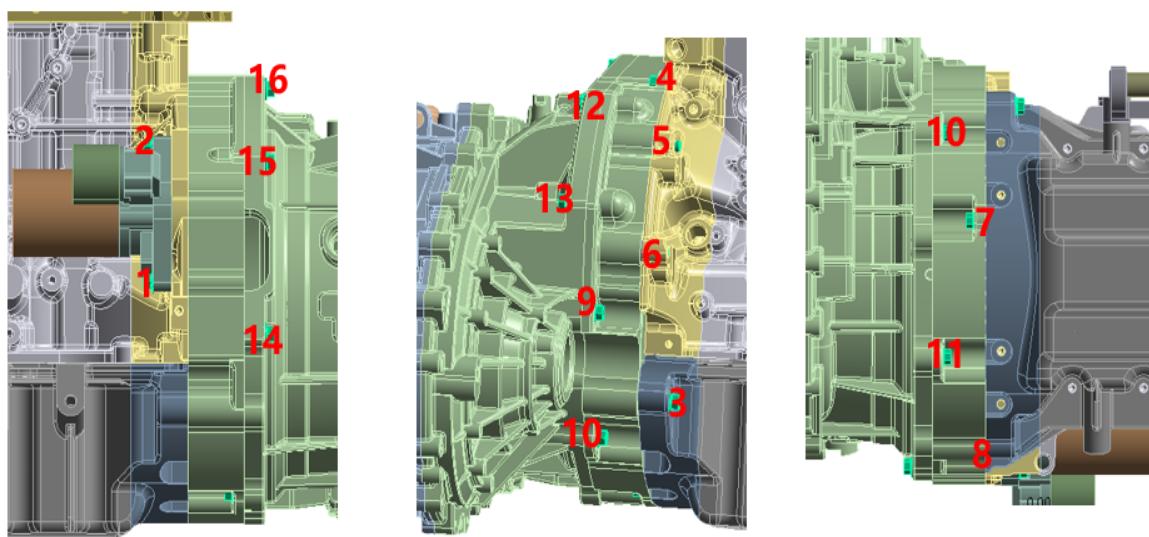


Figure 8. Bolt layout structure (number of bolts).

Due to cost reasons, the specifications of the cylinder block, oil pan, and gearbox holes cannot be changed. Therefore, the bolts used this time are all M10 bolts. Therefore, the 12th bolt has been changed to a 10.9 grade high-strength bolt, and the relevant tightening torque has been specified.

3.6. Vehicle Testing

The connection between the gearbox connecting plate and the gearbox is only effective when it is fixed, so the assessment test needs to be conducted on the entire vehicle. Usually, the transmission connecting plate is mainly subjected to road test impact and vehicle durability test, while checking whether there is any leakage in the relevant sealing parts. The transmission connecting plate developed in this project has passed the relevant tests, indicating that the design is problem free.

4. Conclusions

The transmission connecting plate has been trial produced and has undergone assembly verification and vehicle road testing. Currently, there have been no issues, proving the reliability of this design method. At present, there are many technical solutions for designing transmission connection plates, but there are relatively few examples of short spans between the transmission and the cylinder block. Therefore, this article has the following four guiding significance for the design of connection plates:

- (1) At present, there is no accurate design reference value for the span of the bolt installation holes related to the connecting plate, and the relevant details are not detailed enough. There are many issues that need to be

considered, especially the thickness of the sealing flange. Therefore, how to optimize the relevant plan and clarify the relevant details is a top priority for designers, while achieving weight reduction effects.

- (2) This article uses ADC12 material for the connecting board, which conforms to the trend of lightweighting and provides some reference for material selection of future components.
- (3) This article provides relevant explanations for the overall boundary analysis, especially the roles of components such as the oil pan, gearbox, and starter motor. And the engine cylinder block and gearbox are fixed by relevant suspensions, especially the suspension fixation is not fixed on the cylinder block, but on other components (cylinder head). Therefore, the analysis of this part needs to consider the overall mode and component strength, which has certain reference and guidance significance for the development of engine components.
- (4) Through this article, the load on the connecting plate is confirmed to be standardized, and the risk of bolt strength is also analyzed, providing a certain reference for future finite element analysis of other parts and improving the safety of the connecting plate.

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