# Solution to Diesel Engine Airflow Collision through Exhaust Pipe Modification

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**Abstract: Turbochargers are pivotal diesel engine components that regulate intake and exhaust gas flow rates and pressures via interconnected structures powered by waste gases, ensuring smooth exhaust gas flow and operational efficiency. However, some of our V-type diesel engines experience airflow collisions during exhaust, leading to high fuel consumption and failure to achieve rated power. This study optimizes the exhaust manifold structure by transitioning from the original "turbine end-collective exhaust" design to "turbine end-individual exhaust-collective exhaust", effectively resolving power insufficiency and enabling compliance with factory testing performance requirements. This exhaust manifold optimization for V-type diesel engines is also adaptable to other engine models within our company.**

**Keywords: Exhaust Manifold; Airflow Collision; Diesel Engine Performance; Structural Optimization**

## 1. Introduction

Turbocharging technology, a key means of enhancing internal combustion engine performance, employs engine waste gas kinetic energy to drive turbines, thereby increasing intake pressure. This allows engines to achieve higher power density and fuel efficiency under the same displacement conditions, making it a core component of modern internal combustion engine technology[1]. Given the turbocharging technology, the intake and exhaust channel design directly impacts the turbocharger's response speed and engine combustion efficiency. Rational airflow distribution can reduce intake pulse loss, improve the stability of boost pressure, and prevent turbo lag caused by airflow interference.

Currently, research on improving turbocharger efficiency mainly focuses on optimizing the pressure ratio[2], improving the turbine blade structure[3], and matching the intercooler[4]. Existing studies on airflow collision primarily concentrate on auxiliary components such as exhaust muffler deceleration[5] and particulate filter efficiency enhancement[6]. However, there is a lack of specialized research on the airflow collision issue in the turbocharger exhaust collection area caused by the convergence of waste gases from two turbochargers. This issue can lead to increased exhaust back pressure, waste of waste gas kinetic energy, and other problems affecting turbocharger efficiency, engine efficiency reduction, and component wear.

Therefore, this paper focuses on optimizing the structural design of the turbocharger exhaust system to address airflow collision issues, providing a practical technical solution to enhance the overall turbocharging efficiency of diesel engines. This method can resolve the problem of diesel engines failing to meet performance requirements during factory testing. Moreover, it features a simple structure, minimal space occupation, low cost, and rapid model change capability. It meets the performance requirements for factory testing without affecting the production rhythm or causing lean waste in the workshop.

## 2. Turbocharger Exhaust Manifold Airflow Collision Issue Analysis

### 2.1 Original Exhaust Manifold Structure

The original exhaust manifold structure adopts a "turbine end-collective exhaust" approach, where the turbine end exhaust pipes of the two turbochargers on the V-type diesel engine are directly connected to the transition joint. The red arrows indicate the connection positions of the turbine end exhaust pipes of the two turbochargers on the V-type diesel engine, while the green arrow shows the position where the two gas streams converge and exit after entering the transition joint. The exhaust port of the transition joint is significantly larger than the waste gas inlet.

## 2.2 Airflow Collision Generation Mechanism

Airflow collision refers to the special flow field formed when two or more streams flow at angles (including approximately opposite directions) within a convergence space, undergoing momentum collision and flow interference. Its core characteristics include momentum cancellation in the convergence zone, velocity reconstruction, and enhanced turbulence. This phenomenon is commonly observed in convergence components such as transition joints.

The two exhaust pipes of the turbochargers generate two streams of gas with intake channels arranged at an approximate 90° angle, pointing towards the center of the convergence chamber. After entering the transition joint, the streams carry certain momentum. The difference in their flow directions leads to vector momentum interaction. As the two streams have similar flow rates and pressures, their momentum collision forms a stagnation surface in the convergence zone, causing a sharp drop in flow velocity. The convergence chamber of the transition joint is typically small, lacking sufficient buffer space for the streams to adjust their flow direction. After entering the confined space, the streams cannot slowly diffuse to achieve smooth merging and can only rapidly converge and collide. The resulting flow field disturbance from the collision is difficult to dissipate, thereby intensifying the collision effect.

Additionally, exhaust temperature significantly impacts airflow collision in the exhaust pipe. With exhaust temperatures usually ranging from 400 to 500 °C, the waste gas molecules possess substantial kinetic energy. When high-speed streams collide at the exhaust pipe convergence point, the degree of airflow turbulence increases dramatically, amplifying the collision issue.

## 2.3 Hazards of Airflow Collision

The two streams of gas from the exhaust pipes of the two turbochargers converge at the original exhaust manifold structure and collide. The core issue is that this disrupts the stability of the turbochargers' operation and reduces cylinder combustion efficiency, ultimately resulting in insufficient rated power and torque of the diesel engine and a significant increase in fuel consumption rate, as shown in Table 1. The specific mechanisms are as follows:

The violent collision of the two streams of waste gas triggers airflow turbulence and generates a large number of vortices, disrupting the continuity and stability of the waste gas flow. This prevents the turbine blades from receiving continuous and efficient impact kinetic energy and velocity potential energy. The turbine speed fails to reach its rated condition, thereby causing a decline in the compressor's compression efficiency and insufficient intake boost pressure. The lack of low-pressure fresh air leads to poor fuel atomization quality and reduced gas expansion work in the combustion chamber, directly resulting in insufficient engine rated power and torque.

**Table 1. Important Parameter Table of Diesel Engine Factory Testing under Original Structure**

| Parameter | Lower Limit and Upper Limit | Measured Value | Result |
|---|---|---|---|
| Intercooler outlet air temperature (right) /°C | \ | 208.9 | \ |
| Intercooler outlet air temperature (left) /°C | \ | 192.7 | \ |
| Intercooler outlet air pressure (right) /kPa | 50-60 | 50.6 | Qualified |
| Intercooler outlet air pressure (left) /kPa | 50-60 | 51 | Qualified |
| Power /kW | 666.4-693.6 | 662.1 | Unqualified |
| Torque /N·m | 3535.62-3679.93 | 3513 | Unqualified |
| Exhaust temperature (right) /°C | \ | 22 | \ |
| Exhaust temperature (left) /°C | 550 (Upper Limit) | 445 | Qualified |
| Exhaust back pressure (right) /kPa | \ | -3.7 | \ |
| Exhaust back pressure (left) /kPa | 7.5 (Upper Limit) | -3.7 | Qualified |
| Fuel consumption rate g/(kW·h) | 219.3 (Upper Limit) | 225 | Unqualified |

The turbulence generated by the collision disrupts the periodicity and regularity of the exhaust pulses. The residual waste gas in the cylinder is not thoroughly expelled, diluting the fresh air and causing the air-fuel ratio to deviate from the optimal range. Incomplete fuel combustion occurs as the engine control system automatically increases the fuel injection volume to compensate for the power deficiency. However, under oxygen-deficient conditions, the additional fuel injected cannot fully participate in the combustion reaction. A large amount of energy is wasted in the form of unburned hydrocarbons, creating a cycle of “insufficient power → increased fuel injection → lower combustion efficiency → higher fuel consumption”, further deteriorating the engine's power performance.

## 3. Exhaust Pipe Optimization Design

### 3.1 Design Principles and Concepts

To reduce the interference between the two streams of gas and improve the turbocharger's response speed, enabling the engine to meet performance requirements under rated conditions, two key considerations were made for the exhaust manifold design. First, it is essential to address the issue of airflow collision causing the diesel engine to fail factory testing performance requirements. Second, the optimized structure should not affect the rapid model change and should be compatible with the size of the factory testing bench.

The following transformation concept was thus generated: each exhaust pipe of the V-type diesel engine's turbochargers is separately connected to the exhaust manifold, which then combines the gases and discharges them through a Y-shaped transition joint. The outlet diameter of the transition joint is slightly larger. However, to meet the rapid model change requirement, the dimensions and shapes of each connection interface remain unchanged, with only the intermediate part subjected to lengthening or bending modifications. Additionally, a back pressure sensor is installed at the exhaust pipe of each turbocharger to monitor exhaust resistance, as shown in Figure 1.

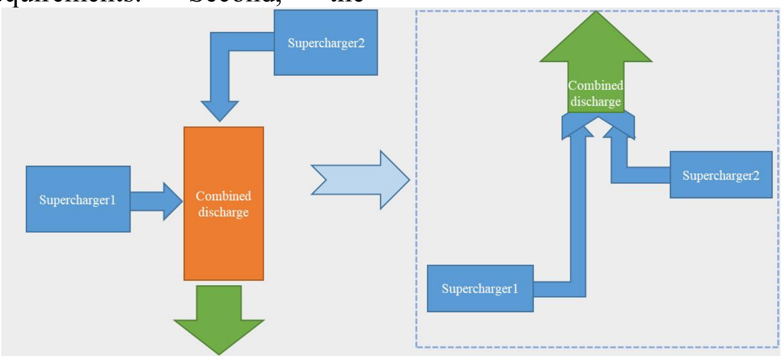
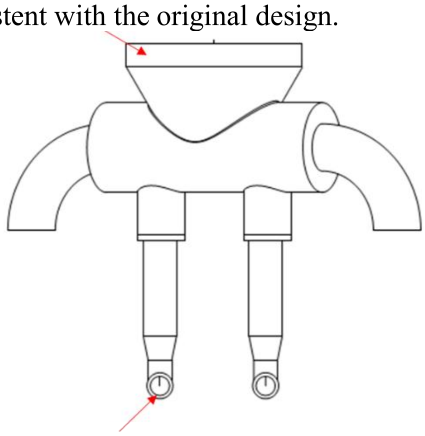



**Figure 1. Exhaust Pipe Structure Modification Schematic**

### 3.2 Transformation Plan

Figure 2 illustrates the transformed exhaust manifold structure, where two independent exhaust pipes are connected to the Y-shaped transition joint's ends to link with the turbocharger's exhaust pipes. In this way, the two streams of gas discharged from the diesel engine are separately discharged and then combined and expelled, avoiding airflow collision. The dimensions of the two connection points remain consistent with the original design.



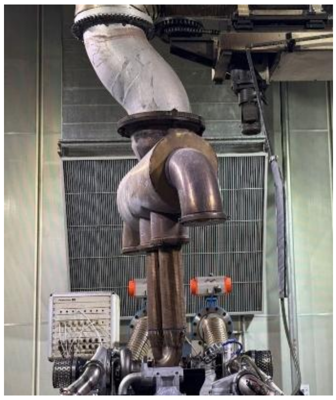


**Figure 2. (a) Modified Exhaust Pipe Structure 2D Drawing, (b) Modified Exhaust Pipe Structurephoto**

## 4. Experimental Verification

### 4.1 Experimental Process

The V-type diesel engine was placed on the factory testing bench, with the oil circuit, water circuit components, and instruments connected as specified. The exhaust pipes of the turbochargers' turbine ends were connected to separate exhaust pipes for gas discharge. Meanwhile, engine oil was introduced for lubrication, coolant was added for cooling, and diesel fuel was supplied. The diesel engine was connected to a dynamometer for testing under load. Observations were made for any leaks, and data reflecting the engine's operating performance under different conditions were collected.

### 4.2 Experimental Results and Comparison

As shown in Table 2, when the improved exhaust manifold structure was used, the waste gas passed through two parallel exhaust pipes and was finally combined and discharged through the transition joint. This waste gas discharge path avoided the generation of airflow collision. The waste gas discharge maintained a reasonable and regular pulse cycle, ensuring continuous power supply to the turbine blades and meeting the intake boost pressure requirements. Consequently, the combustion chamber's expansion work was normal. As presented in Table 2, the engine's rated power and torque both met the requirements under the improved structure.

**Table 2. Key parameters of diesel engine before and after improvement**

| Parameter | Lower Limit and Upper Limit | Measured Value before Improvement | Measured Value after Improvement |
|---|---|---|---|
| Intercooler outlet air temperature (right) /℃ | \ | 208.9 | 210.4 |
| Intercooler outlet air temperature (left) /℃ | \ | 192.7 | 190.1 |
| Intercooler outlet air pressure (right) /kPa | 50-60 | 50.6 | 53.9 |
| Intercooler outlet air pressure (left) /kPa | 50-60 | 51 | 52 |
| Power /kW | 666.4-693.6 | 662.1 | 671 |
| Torque /N·m | 3535.62-3679.93 | 3513 | 3552 |
| Exhaust temperature (right) /℃ | \ | 22 | 454 |
| Exhaust temperature (left) /℃ | 550 (Upper Limit) | 445 | 454 |
| Exhaust back pressure (right) /kPa | \ | -3.7 | -3.8 |
| Exhaust back pressure (left) /kPa | 7.5 (Upper Limit) | -3.7 | -3.8 |
| Fuel consumption rate g/(kW·h) | 219.3 (Upper Limit) | 225 | 217.1 |

As shown in Figure 3, under rated conditions during factory testing, the torque before improvement was 3513 N·m, 22.62 N·m below the lower limit. After improvement, the measured value was 3552 N·m, within the upper and lower limits, meeting the requirements, with an increase of 11.1‰. Under rated conditions during factory testing, the power before improvement was 662.1 kW, 4.3 kW below the lower limit. After improvement, the measured value was 671 kW, within the upper and lower limits, meeting the requirements, with an increase of 13.4‰. Under rated conditions during factory testing, the fuel consumption rate before improvement was 225 g/(kW·h), 5.7 g/(kW·h) above the upper limit. After improvement, the measured value was 217.1 g/(kW·h), within the upper and lower limits, meeting the requirements, with a decrease of 35.1‰. Overall, after the structural improvement, the torque, power, and fuel consumption rate all met the factory testing requirements under rated conditions.

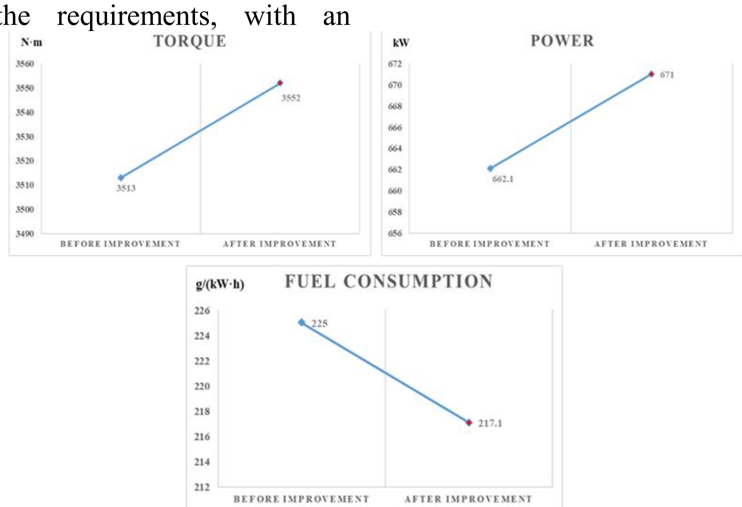



**Figure 3. Line Chart of Torque, Power, and Fuel Consumption Before and After Improvement**

## 5. Conclusion

This paper proposes a method to address the issue of V-type diesel engines failing to meet factory testing performance requirements due to exhaust airflow collision. The method involves optimizing the exhaust manifold structure by transitioning from the original “turbine end-collective exhaust” to “turbine end-individual exhaust-collective exhaust”. This resolves the issues of insufficient rated power and high fuel consumption. The success of this transformation lies in addressing insufficient turbine end power and poor exhaust pulse cycles. Moreover, the transformation is cost-effective, simple in structure, and highly operational. The optimized exhaust manifold structure effectively resolves airflow collision issues and enhances engine power and fuel economy. It provides a practical and feasible reference for optimizing the exhaust manifold of other diesel engine models in our company and is highly adaptable.

## References

[1] Yu Chao. Research on the Application of Turbocharging Technology in Automotive Internal Combustion Engines[J]. Internal Combustion Engines & Parts, 2025, (15): 104-106.

[2] Zhao Minghao, Yin Yong, Zhao Yanting, et al. Simulation Study on Matching of Two-Stage Turbocharging System for Heavy-Duty Diesel Engines[J]. Chinese Internal Combustion Engine Engineering, 2024, 45(02): 64-74.

[3] Zhang Yucheng. Study on the Characteristics of Turbocharger Turbine Blades[D]. Shanghai University of Engineering Science, 2017.

[4] Zhang Wei, Yang Jue, Zhang Wenming, et al. Experimental Study on the Influence of Intercooler Layout on the Performance of Internal Combustion Engine Cooling System[J]. Journal of Northeastern University (Natural Science Edition), 2015, 36(05): 719-723.

[5] Zhang Yiqiang, Wu Pei, Su He, et al. Study on Pressure Loss of Diesel Engine Split Gas Impingement Coupled Muffler[J]. Noise and Vibration Control, 2022, 42(05): 260-267.

[6] Cauda E, Mescia D, Fino D, et al. Diesel Particulate Filtration and Combustion in a Wall-Flow Trap Hosting a $LiCrO_2$ Catalyst[J]. Industrial & Engineering Chemistry Research, 2018, 57(12):4568 - 4576