Performance Evaluation of Twin-Scroll Wastegated Turbocharger to Match with 3.0 Litre Diesel Engine

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Abstract. This study investigated the compatibility and performance of a twin-scroll wastegated turbocharger to match a 3.0-liter diesel engine, which can produce the power output of 300 hp - 550 hp. The twin-scroll wastegated turbocharger is selected from the BorgWarner turbocharger of the EFR model series. This study utilized the web-based turbocharger matching tool, which is operated by inputting engine-specific parameters and simulating performance targets. Throughout the process, context-sensitive guidance is provided, including recommended ranges for complex parameters such as Brake Specific Fuel Consumption (BSFC), Volumetric Efficiency (VE), and exhaust gas temperature. Upon completion of data entry, the tool outputs detailed compressor and turbine performance metrics, including characteristic maps. Based on the simulated input and performance outputs, the EFR 7064-C turbocharger was selected as the optimal match, aligning well with the engine's power requirements and operational characteristics.

INTRODUCTION

Turbocharging has become a key technology for improving the performance and efficiency of internal combustion engines (Kennedy et al., 2018), especially in diesel-powered vehicles where high torque and fuel savings are vital. For a 3.0-liter diesel engine, choosing the right size turbocharger is crucial to achieving the desired boost response, thermal efficiency, and durability under various load conditions. This research focuses on selecting and examining the impact of a twin-scroll wastegated turbocharger on a 3.0L diesel engine.

A 3.0-liter turbocharged diesel engine is a type of internal combustion engine that uses diesel fuel and features a total displacement of 3.0 litre. It operates by compressing air to a high pressure and temperature, then injecting diesel fuel directly into the combustion chamber, where it ignites due to the heat generated by compression. This process is known as compression ignition. The engine is equipped with a turbocharger, which uses the energy from exhaust gases to drive a turbine that compresses incoming air. This compressed air increases the oxygen concentration in the cylinders, allowing more fuel to burn efficiently and resulting in greater power and torque output, especially at lower engine speeds. It is widely used in applications that require strong pulling power, fuel efficiency, and long service life, such as in pick-up trucks, SUVs, commercial vehicles, off-road and utility vehicles. It differs to certain types of engines which could be figured out and summarized as in Table 1.

TABLE 1: Summary of difference engine type

Feature	Turbo-diesel	NA-diesel	Turbo-gasoline	NA-gasoline
Fuel type	Diesel	Diesel	Gasoline	Gasoline
Combustion type	Compression	Compression	Spark	Spark
Air induction type	Air boost	N.A	Air boost	N.A
Torque	Very high	moderate	Moderate-high	Low-moderate

Power	High	Low-moderate	High	Moderate
Durability	High	moderate	Moderate-high	Low
Fuel economy	Excellent	High	Moderate	Lower

The term “Twin-scroll” describes a turbine housing with two separate volute channels, through which exhaust gases and energy flow. Wastegate is a critical component that manages the turbine’s speed and controls boost pressure by diverting excess exhaust gases away from the turbine wheel (Casey & Robinson, 2021). In this study, the EFR 7064-C turbocharger is chosen for its high-performance characteristics, including its power output. It features a twin-scroll wastegate, which improves exhaust energy utilization by separating exhaust pulses (Feneley et al., 2016), reducing reversion losses (Thiyagarajan et al., 2020), and enhancing turbine efficiency compared to a single-scroll design. Today, numerous manufacturers worldwide produce a wide variety of turbocharger designs to meet increasing market demands. BorgWarner stands out as a notable specialist with over 50 years of experience supplying turbochargers for various applications, such as passenger cars, commercial vehicles, industrial machinery, locomotives, and marine engines. The company is renowned globally for its innovation in turbocharging technology and maintains some of the industry’s highest product validation standards. They also developed an internet-based tool called Match-Bot, which helps customers select the optimal turbocharger by entering specific engine data.

Traditionally, selecting a turbocharger involved manual calculations or empirical judgments, which could be time-consuming and might not lead to the best match. To improve this process, BorgWarner created the Match-Bot™ tool, which is an interactive, web-based application that simplifies turbocharger selection. Engineers can input engine parameters and quickly view performance maps to identify suitable options. This study utilizes the matching tool to evaluate the suitability of the EFR 7064-C turbocharger for a high-efficiency, responsive 3.0-liter diesel engine. The analysis considers both steady-state and transient performance aspects, focusing on balancing turbo lag, peak airflow, and compressor efficiency. The goal is to determine if the EFR 7064-C provides an optimal compromise between performance and reliability for diesel engine applications

LITERATURE REVIEW

Historically, conducting detailed analyses of turbocharger performance was often difficult due to complex evaluation methods and the lack of modern matching tools. Researchers, automotive experts, and vehicle operators faced challenges due to the absence of a systematic approach for selecting suitable turbochargers tailored to specific engine needs, especially when relying on automated numerical simulations and data processing. Consequently, much of the work had to be done manually, increasing the risk of overlooking important data and hampering efficient progress in research. This often resulted in incomplete assessments, suboptimal results, and reliance solely on general catalogues or basic data sheets. Such limitations posed a significant disadvantage for those seeking comprehensive product information from manufacturers or suppliers.

This study also emphasizes the importance of turbine housing design. The key difference lies in the configuration of the turbine housing, which greatly influences exhaust gas flow dynamics, turbocharger efficiency, and overall engine performance. In this research, a twin-scroll wastegated type is selected because it provides better control of exhaust energy, helping to sustain high efficiency over a broader operating range (Cassey et al., 2021). In single-scroll designs, all exhaust pulses from the cylinders are combined into a single volute before reaching the turbine wheel. Conversely, twin-scroll wastegated turbochargers utilize a divided turbine housing that separates exhaust gases from different cylinder groups. Unlike twin-scroll or variable geometry options, single-scroll layouts do not distinguish between exhaust pulses from individual cylinders (Macek et al., 2015). Although single-scroll wastegate turbochargers are still widely used, particularly for light-duty diesel and gasoline engines, due to their cost-effectiveness, simplicity, and proven reliability, this configuration presents several drawbacks when subjected to dynamic operational demands. While this simplifies the design, it often results in less effective pulse energy recovery and greater interference between exhaust pulses, particularly at lower engine speeds (Blanco, 2020). One major limitation is turbo lag, especially at lower engine speeds where diesel engines typically operate to generate high torque. The merging of exhaust pulses within a single scroll reduces energy transfer efficiency, delaying boost buildup and resulting in slower sluggish-throttle response under transient loads such as acceleration or load shifts (He et al., 2017). Additionally, the exhaust pulse interference is a concern in single-scroll systems. Because all cylinders share the same scroll, the exhaust pulses from multiple cylinders can overlap and interfere with one another.

To address these challenges, it becomes necessary to investigate the compatibility and performance benefits of twin-scroll wastegated turbochargers in diesel engines. The twin-scroll design offers significant advantages in improving transient response and overall efficiency, especially at low and mid-load conditions (Walkingshaw et al., 2015). However, optimizing wastegate calibration and turbine size can help reduce turbo lag significantly. The wastegate design also significantly impacts on turbocharger performance. Furthermore, the associated wastegate system, designed to regulate excess boost, may open frequently during part-load conditions. This limits turbine operation, causing a drop in boost pressure and resulting in inconsistent engine performance and lower fuel efficiency. This reduces the scavenging effect and increases exhaust backpressure, ultimately compromising volumetric efficiency and combustion quality.

Wastegate flow recirculation and turbulence levels considerably affect turbine efficiency and boost stability (Barbosa, 2016). As a result, modern designs increasingly incorporate aerodynamically optimized wastegate passages and refined scroll geometries to enhance performance. Larger wastegate ports and advanced actuator strategies have been demonstrated to improve transient response without sacrificing high-load performance (Elmagdoub et al., 2022). From a thermal perspective, single-scroll wastegated turbochargers can be more vulnerable to heat soak during sustained high-load conditions. Prolonged heavy loads keep exhaust gases hot, transferring more heat to the turbocharger and exacerbating heat soak issues. Such heat buildup can cause oil breakdown, deposit formation, and damage to bearings and other components. Overall, twin-scroll turbochargers tend to be more resistant to heat soak. Their simpler volute geometries often create localized hot spots, which can accelerate material degradation if not managed with advanced materials and cooling strategies.

METHODOLOGY

The approach used in this study involves employing an online matching tool called Match-bot to pair a twin-scroll wastegated turbocharger with a 3.0-liter diesel engine. Match-bot is a web-based, data-driven platform designed to aid in selecting and configuring turbochargers based on user-input parameters. The process begins by entering data into two main categories:

a. *Engine Specifications – This includes key performance parameters such as engine displacement, desired boost pressure, target power output, and exhaust gas properties.*

b. *Turbocharger Parameters – This covers specific operational conditions and requirements related to both the compressor and turbine components of the turbocharger.*

After inputting the necessary data, the software produces a detailed set of results. These include calculated performance metrics for the compressor and turbine, efficiency maps, and visual representations like flow maps for both components. The platform allows users to iteratively adjust input parameters to assess their performance effects, enabling the selection of an optimal turbocharger that matches the engine's operational profile. This methodology offers a data-driven, efficient, and precise matching process, significantly enhancing accuracy and effectiveness compared to traditional manual selection methods.

Turbochargers are centrifugal compressors powered by exhaust gas turbines, commonly used in engines to enhance air pressure intake. Their performance significantly affects key engine attributes, including power output, fuel efficiency, and emission levels. As illustrated in **Fig.1**, a turbocharger comprises a turbine wheel and a compressor wheel connected via a common shaft. The exhaust gases from the engine flow into the turbine, causing it to spin rapidly due to the high-energy gas flow. Because the turbine and compressor share the same shaft, the rotation of the turbine directly drives the compressor. Once the desired boost pressure is reached, any excess exhaust gas is redirected through the wastegate, which prevents over-speeding of the compressor and avoids engine knocking (Feneley et al., 2016). While spinning, the compressor draws in air, which is filtered and then compressed, increasing both its temperature and pressure. This compressed air is then passed through a charge air cooler, where its density and volumetric efficiency are improved before entering the engine. The result is enhanced combustion, leading to greater engine performance and improved fuel economy.

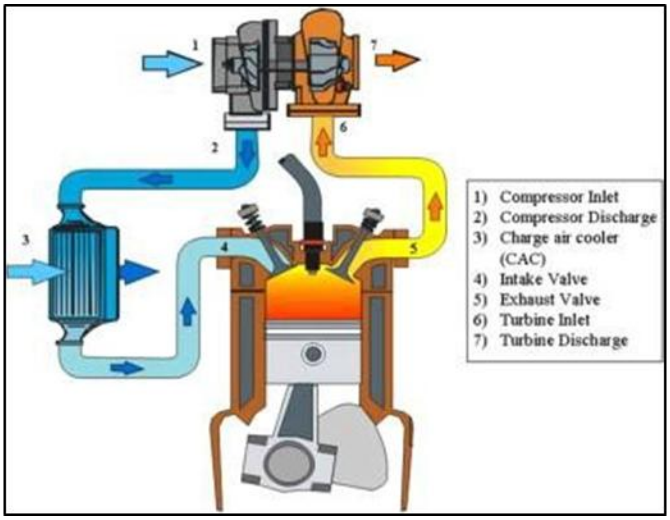


FIGURE 1: Turbocharger system

Basic Engine Parameters Configuration

The upper segment of the Matching-tool interface is designed to capture critical engine parameters, as illustrated in **Fig.2**. This step represents the initial phase of the turbocharger selection procedure. For this study, the engine evaluated is a 3.0-liter diesel powerplant featuring a single turbocharger configuration. It is imperative that all fields within the engine requirements module are precisely and thoroughly completed prior to progressing to the subsequent stages of the matching workflow.

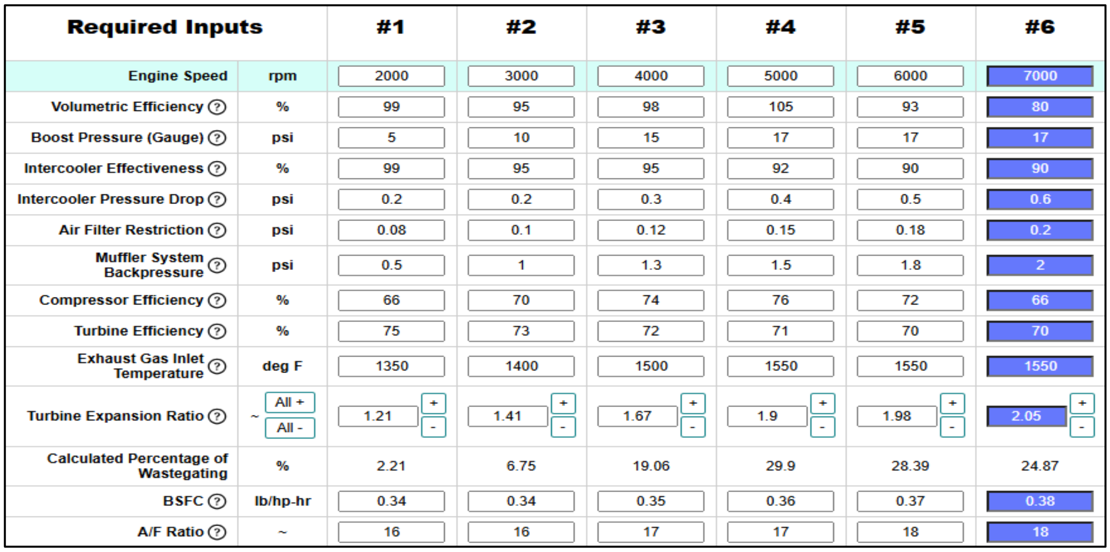
Enter Engine Information (Required)

Turbo Configuration	Single Turbo
Displacement (Liters)	3.0 (183.06 CID)
Ambient Air Temp (deg F)	86
Altitude (ft above sea level)	51 (14.685 psi barometric pressure)
Fuel Type	Diesel

FIGURE 2: Basic engine information

Configuration Of Specific Engine Input Parameters

Subsequently, users should proceed to input the remaining required parameters in the second section of the interface, as depicted in **Fig.3**.



Required Inputs		#1	#2	#3	#4	#5	#6
Engine Speed	rpm	2000	3000	4000	5000	6000	7000
Volumetric Efficiency ?	%	99	95	98	105	93	80
Boost Pressure (Gauge) ?	psi	5	10	15	17	17	17
Intercooler Effectiveness ?	%	99	95	95	92	90	90
Intercooler Pressure Drop ?	psi	0.2	0.2	0.3	0.4	0.5	0.6
Air Filter Restriction ?	psi	0.08	0.1	0.12	0.15	0.18	0.2
Muffler System Backpressure ?	psi	0.5	1	1.3	1.5	1.8	2
Compressor Efficiency ?	%	66	70	74	76	72	66
Turbine Efficiency ?	%	75	73	72	71	70	70
Exhaust Gas Inlet Temperature ?	deg F	1350	1400	1500	1550	1550	1550
Turbine Expansion Ratio ?	~ All + All -	1.21 + -	1.41 + -	1.67 + -	1.9 + -	1.98 + -	2.05 + -
Calculated Percentage of Wastegating	%	2.21	6.75	19.06	29.9	28.39	24.87
BSFC ?	lb/hp-hr	0.34	0.34	0.35	0.36	0.37	0.38
A/F Ratio ?	~	16	16	17	17	18	18

FIGURE 3: Further input requirement

These inputs are critical, as they have a direct impact on the calculated performance characteristics of both the compressor and turbine components. Engine speed data must be entered at six predefined points, typically spanning from 2000 to 7000 RPM, which reflects the operational range of a 3.0- liter diesel engine under high torque conditions. Volumetric efficiency, which measures the engine's ability to fill its cylinders with air, is influenced by design factors and the fuel type used. For diesel engines of this displacement, a volumetric efficiency of 90% or higher is generally advisable. This parameter typically improves as engine speed increases. Boost efficiency refers to the expected boost pressure that must be achieved by the turbine across varying engine speeds. At lower RPMs, minimal boost is required, with a gradual increase expected as engine speed rises.

The effectiveness of the intercooler is also a vital consideration. An ideal assumption is 100% effectiveness, meaning that the temperature of the charge air after cooling matches ambient air temperature. Intercooler pressure drops account for pressure losses within the intercooler and its associated ducting, commonly falling within the range of 1 to 2 psi at peak load conditions. Air filter restriction represents the pressure drop incurred before air reaches the engine intake. For systems utilizing high-efficiency filters, this drop is minimal, typically around 0.5 psi, and should not exceed 1 psi even under full load. Muffler backpressure is the resistance encountered in the exhaust system due to the muffler and can rise to between 6 and 7 psi during high-load operation.

Compressor efficiency is defined by the unit's capability to deliver the target pressure ratio while minimizing heat generation. In contrast, turbine efficiency is the ratio of actual mechanical work output to the total thermal energy available from the exhaust gases. As engine speed increases, turbine efficiency generally declines due to elevated thermal and pressure losses. Lastly, the turbine expansion ratio is a pivotal input, as it governs wastegate flow calculations. This parameter may require iterative adjustment to ensure that all operating conditions align with a single phi curve on the turbine performance map.

Calculation Formula of Certain Inputs

For further clarity, several of the necessary input parameters are traditionally derived using established engineering formulas. However, within the Matching-tool environment, these computations are handled automatically by the integrated calculation engine, which streamlines the generation of performance outputs. This system also supports the visualization of compressor and turbine maps. Illustrative examples of such formulas are used for determining volumetric efficiency, pressure ratio, and corrected compressor mass airflow are presented below.

Engine Volumetric Efficiency (η_v)

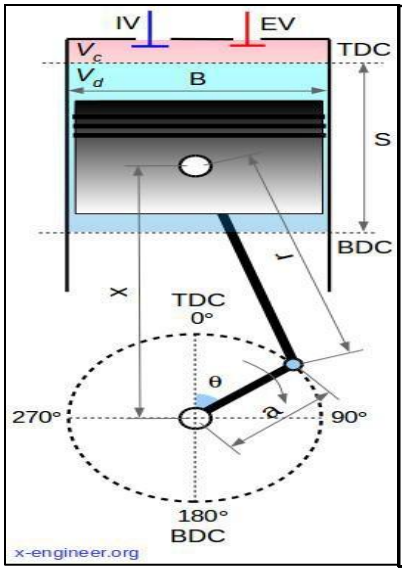
The **volumetric efficiency** (η_v) of an engine refers to how effectively the engine fills its cylinders with air during the intake process. In other words, it is the proportion of the actual intake air volume, drawn into the cylinder/engine over the theoretical displacement/swept volume, throughout the intake cycle. It is calculated as the following equations.

$$\text{Volumetric efficiency, } \eta_v = (V_a / V_d) \,.\, 100\% \qquad (1)$$

where,

V_a [m^3] = actual intake air volume
V_d [m^3] = displacement/swept volume of cylinder engine

Referring to **Fig.4**, it shows the diagram of the engine volumetric parameters which will be used in volumetric efficiency calculation, it shows the diagram of the engine volumetric parameters which will be used in volumetric efficiency calculation.



IV = intake valve
EV = exhaust valve
TDC = top dead center
BDC = bottom dead center
B = cylinder bore
S = piston stroke
r = connecting rod length
a = crank radius (offset)
x = distance between the crank axis and the piston pin axis
θ = crank angle
Vd = displaced (swept) volume
Vc = clearance volume

FIGURE 4: Engine volumetric parameters

$$V_a \, [m^3] = m_a / \rho_a \qquad (2)$$

where,

m_a [kg] = mass of air
ρ_a [kg/m^3] = air density

Replacing (2) in (1) gives the volumetric efficiency equal to:

$$\eta_v = m_a / (\rho_a \cdot V_d) \qquad (3)$$

In most engine dynamometer tests, the intake air is measured as a mass flow rate rather than as a total air mass [kg]. As a result, the volumetric efficiency calculation must be based on the air mass flow rate.

$$\dot{m}a \text{ [kg/s]} = (ma \cdot N) / nr \qquad (4)$$

where,

$\dot{m}a$ [kg/s] = air mass flow rate N [rpm] = engine speed
nr [-] = number of crankshaft rotations for a complete engine cycle

From equation (3), we can write the intake air mass as:

$$ma\ [kg] = (\dot{m}a \cdot nr) / N \qquad (5)$$

Replacing (5) in (3) gives the volumetric efficiency equal with ;

$$\eta v = (\dot{m}a \cdot nr) / (\rho a \cdot Vd \cdot N) \qquad (6)$$

Volumetric efficiency reaches a maximum value of 1.00 (or 100 indicating that the engine is drawing in the full theoretical volume of air. In certain specialized designs optimized for a specific operating condition, it is possible for volumetric efficiency to slightly exceed 100%. When the intake manifold pressure and temperature are known, the corresponding intake air density can be determined using the following expression :

$$\rho a\ [kg/m3] = Pa / (Ra \cdot Ta) \qquad (7)$$

where,

Pa [Pa] = intake air pressure /intake manifold pressure
Ta [K] = intake air temperature / intake manifold temperature
Ra [J/kgK] = gas constant for dry air (equal to 286.9 J/kgK)

Compressor Corrected Mass Flow Rate

From the compressor output map, the corrected mass flow rate is assumed as compressible mass flow, which is calculated such as below,

$$\dot{m}_{corr}\ [kg/s] = \dot{m}_a \cdot \sqrt{}\,(T_t / T_{ref}) \cdot (P_{ref} \cdot P_t)$$

or, the actual corrected mass flow rate can be calculated as,

$$\dot{m}_{corr}\ [kg/s] = (A \cdot P_t / \sqrt{}\,[T_t]) \cdot \sqrt{}\,(\gamma / R) \cdot M \cdot [1 + M\text{^}2 \cdot (\gamma -1) / 2]\text{^}-[(\gamma +1) / 2(\gamma -1)]$$

where,

$\dot{m}_{corr}$ [kg/s] = corrected mass flow rate / compressible mass flow
$\dot{m}$ [kg/s] = mass flow rate A [m^2] = tube area
γ = specific heat Ratio P_t [Pa] = total pressure
T_t [K] = total Temperature M = mach number
R = gas constant

Compressor Pressure Ratio (CPR)

$$\text{Compressor pressure ratio, CPR [Pa]} = P_{2t} / P_{1t}$$

Where,

P2t [Pa] = total compressor outlet pressure
P1t [Pa] = total compressor inlet pressure

Turbine Flow Parameter / turbine swallowing (Phi)

$$\text{Turbine flow parameter (phi)} = \dot{m} \cdot \sqrt{Tt} / Pt$$

Where,

$\dot{m}$ = Mass flow rate
T_t = total Temperature P_t = total pressure

Turbine Expansion Ratio / Turbine Pressure Ratio (TER/TPR)

$$\text{Turbine expansion/pressure ratio, TER / TPR [Pa]} = P_5 / P_4$$

Where,

P5 [Pa] = total turbine outlet pressure
P4 [Pa] = total turbine inlet pressure

RESULT

This section presents the outcomes generated by the turbocharger matching tool, highlighting key parameters essential for selecting an appropriate turbocharger. A comprehensive evaluation of these results will be performed to identify the most suitable turbocharger configuration. The primary outputs obtained from the matching tool include the calculated compressor performance, turbine performance, and the corresponding compressor and turbine maps.

Compressor Calculated Output

Once the input parameters are entered, the turbocharger matching tool generates the results immediately. **TABLE 1** illustrates the calculated output for the compressor. Typically, as engine RPM increases, the compressor's performance metrics also exhibit a corresponding rise, with all output parameters increasing proportionally with RPM.

TABLE 1: Compressor calculated output

Output parameters	unit	2k rpm	3k rpm	4k rpm	5k rpm	6k rpm	7k rpm
Compressor pressure ratio	~	1.36	1.71	2.06	2.21	2.22	2.23
Compressor outlet temperature	deg F	160.4	212.2	252.1	265.2	276.6	295.4
Intake manifold air temperature	deg F	85.75	91.36	93.35	99.42	104.16	106.04
Intake manifold air density	lb/in3	0.00056	0.00007	0.000084	0.000089	0.000088	0.000088

Density ratio (Intercooled)	~	1.34	1.66	1.99	2.1	2.08	2.08
Corrected air flow rate	Kg/sec	0.077	0.138	0.228	0.323	0.341	0.342
1/BSAC	hp-min/lb	11	11	10	9.7	8.9	8.7
Turboshaft power	hp	4.13	13.25	28.69	43.76	49.04	53.85
Engine power	hp	105.9	201.4	303.5	417.2	404	393.5
Engine torque	lb-ft	278.07	352.8	398.45	438.21	353.86	295.34
Fuel requirement	lb/hr	36	68.5	106.2	150.2	149.5	149.5

Turbine Calculated Output

Unlike compressor calculated output, **TABLE 2** shows most of turbine output parameters decrease slightly downward due to few conditions.

TABLE 2: Turbine calculated output

Output parameters	**unit**	**2k rpm**	**3k rpm**	**4k rpm**	**5k rpm**	**6k rpm**	**7k rpm**
Exhaust manifold pressure	psi	3.7	7.4	12	16.1	18	19.5
Engine delta pressure (dP)	psi	1	3	3	1	-1	-3
Turbine swallowing parameter	PHI	0.0201	0.0288	0.035	0.0376	0.0381	0.0381
Turbine corrected flow @ (59) F	lb/min	14.9	21.4	26	28	28.4	28.5
Wastegate flow area @ CF=0.9	In2	0.03	0.1	0.36	0.7	0.66	0.55
Wastegate port diameter requirement	mm	5	9	17	24	23	21

Compressor Output Map

Fig.5 illustrates the compressor map for the EFR 7064 turbocharger. All operating points are positioned well within the map's efficiency islands, safely avoiding both the surge and choke regions. At low engine speed, the compressor operates at a pressure ratio of 1.36 psi, with an airflow rate of 0.073 kg/s, a wheel speed of 69,033 RPM, and an efficiency of 58%, positioned near the surge line. At the highest engine speed, the pressure ratio rises to 2.23 psi, with airflow reaching 0.342 kg/s and the compressor spinning at 73,635 RPM with 67% efficiency. The peak efficiency recorded is 68%, occurring at a compressor speed of 84,681 RPM.

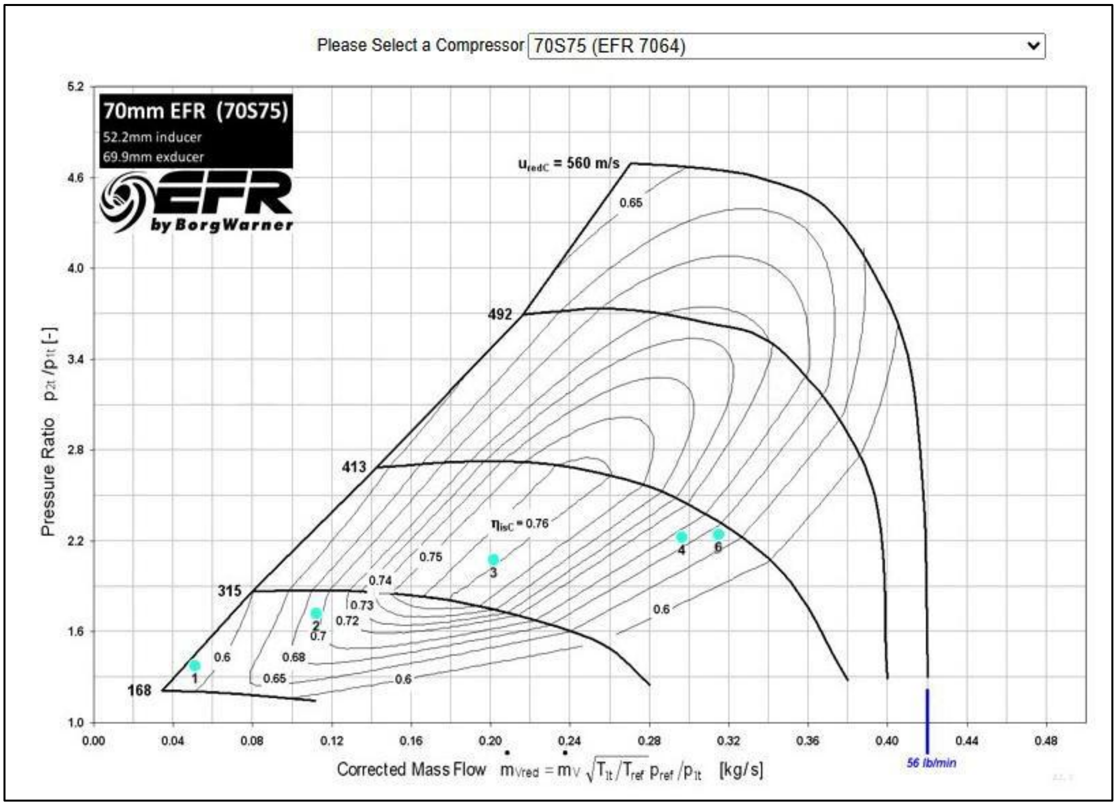
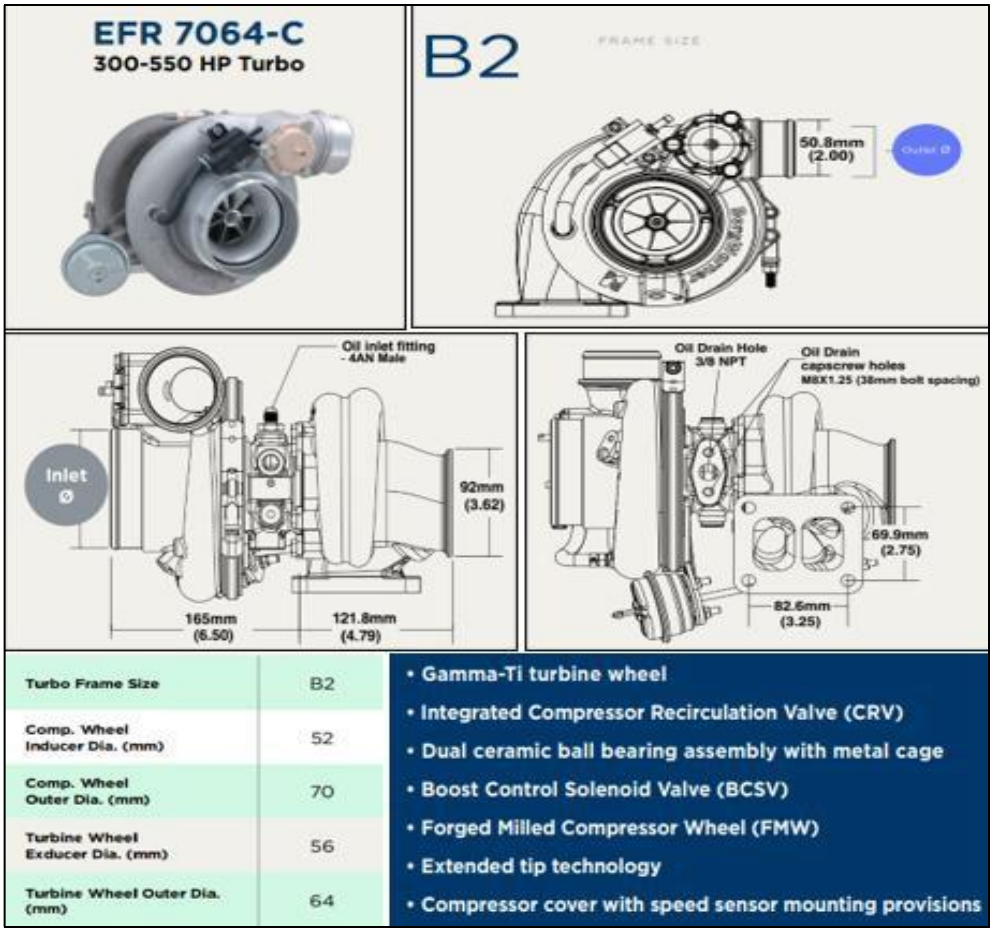


FIGURE 6: Turbine output map

EFR 7064-C Turbocharger Model & Frame Dimension

Upon completion of the simulation analysis for the target turbocharger, the **BorgWarner EFR 7064-C** was identified as the optimal choice. This model offers several notable features and supports a horsepower range between 300 hp and 550 hp. **Fig.7** presents the diagram of the selected turbocharger model, including its frame dimensions, created using BorgWarner's advanced industrial design software.



Turbo Frame Size	B2
Comp. Wheel Inducer Dia. (mm)	52
Comp. Wheel Outer Dia. (mm)	70
Turbine Wheel Exducer Dia. (mm)	56
Turbine Wheel Outer Dia. (mm)	64

- Gamma-Ti turbine wheel
- Integrated Compressor Recirculation Valve (CRV)
- Dual ceramic ball bearing assembly with metal cage
- Boost Control Solenoid Valve (BCSV)
- Forged Milled Compressor Wheel (FMW)
- Extended tip technology
- Compressor cover with speed sensor mounting provisions

FIGURE 7: EFR7064-C twin scroll turbocharger & frame dimension

Besides, there are other specification detail of this turbocharger which can be referred as in **TABLE 3.**

TABLE 3: Borg Warner EFR 7064-C turbocharger information detail

Specification Detail	
Compressor Wheel Inducer Diameter	52 mm
Compressor Wheel Outer Diameter	70 mm
Turbine Wheel Exducer Diameter	56 mm
Turbine Wheel Outer Diameter	64 mm
A/R	0.92
Bearing Housing Material	Aluminium
Inlet Flange Shape	T-4
Turbine Housing Config.	twin scroll
Horse Power Range	300hp – 550hp

DISCUSSION

This study evaluates the performance of the BorgWarner EFR 7064-C turbocharger using BorgWarner's online matching tool, which helps select the right turbo by simulating engine conditions. The tool relies on compressor and turbine maps to determine the best match for a specific engine. The process begins by inputting basic engine specs, followed by additional parameters to simulate performance and find an optimal fit. Theoretically, twin-scroll turbochargers are known to offer superior performance characteristics compared to single-scroll turbochargers (Labade et al., 2022). However, analyzing the use of twin-scroll turbochargers in 3.0 litre diesel engines compared to other engine type will demonstrate the importance of this compatibility study. The EFR 7064-C was chosen for its strong performance when paired with a 3.0-liter diesel engine. It features a twin-scroll turbine housing and an electronically controlled internal wastegate. Designed for high performance and racing applications, this turbo can support 300–550 horsepower. The twin-scroll setup was preferred over a single-scroll because of its better performance. **Fig.8** compares single-scroll and twin-scroll turbine housing.

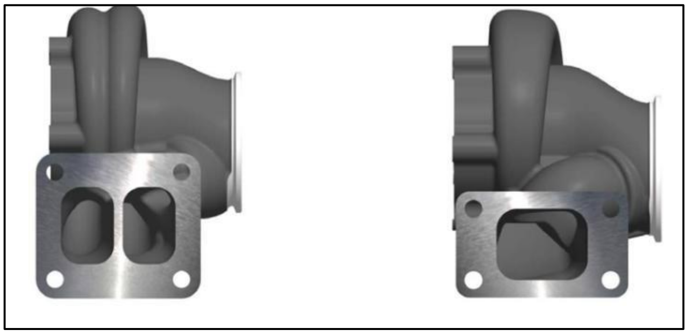


FIGURE 8: Two scroll housing vs single scroll housing

Twin-scroll turbos generally provide quicker spool-up, reduced turbo lag, better low-end torque, and greater efficiency by separating exhaust pulses and improving gas flow.

The compressor map is a key tool for verifying turbo suitability. For the EFR 7064-C, all operating points stay well within the map's stable region away from surge or choke zones indicating strong performance even at high RPMs. This confirms that the compressor is correctly sized, with an appropriate A/R ratio, delivering good efficiency and stability under different load conditions. As RPM increases, so does the boost pressure and compressor output. This improves compressor efficiency and airflow. However, the intake manifold temperature also rises due to heat transfer and reduced intercooler efficiency at high speeds. While compressed air passes through the intercooler, its effectiveness drops at higher temperatures, increasing intake temperatures.

With rising RPM, intake air density also increases because of higher volumetric efficiency and manifold pressure. Peak volumetric efficiency over 110%occurs near 4000 RPM. This is due to optimized valve timing, intake resonance effects, and minimal losses. At this speed, the turbo is fully spooled, and airflow is at its most efficient. Above 4000 RPM, volumetric efficiency decreases due to reduced intake stroke time, higher friction and turbulence, valve timing limitations, increased backpressure, and rising intake air temperatures that lower oxygen density.

For turbine performance, exhaust pressure rises with engine speed due to higher volumetric efficiency and diesel engines' naturally high compression ratios. The turbine map uses the expansion ratio (inlet pressure vs. ambient) to assess turbine performance. Proper turbine matching ensures that this ratio aligns with the engine's exhaust flow, influenced by the A/R ratio of 0.92 in the EFR 7064-C. The turbo's internal wastegate starts operating around 15–17 psi of boost. At engine speeds above 3500 RPM, more exhaust gas is routed through the wastegate. While the tool does not simulate all turbine dynamics, the EFR 7064-C stays within acceptable performance limits. No signs of over-boost or wastegate issues were observed, indicating good boost control and low back pressure under steady conditions.

CONCLUSION

In conclusion, the Match-Bot turbocharger tool provides a fast and easy-to-use method for choosing the ideal BorgWarner turbocharger model. It instantly generates numerical results and graphically displays them on compressor and turbine maps, removing the necessity for manual calculations or complicated selection steps. This application greatly streamlines the turbocharger matching process, saving both time and effort. Furthermore, it offers detailed performance data for both the compressor and turbine, allowing users to conduct thorough analyses and make informed engineering choices. Overall, while single-scroll turbochargers are suitable for basic applications with lower performance demands, twin-scroll turbochargers are the superior choice for modern diesel engines requiring enhanced responsiveness, reduced turbo lag, and improved volumetric efficiency. Therefore, for high-performance and efficiency-critical diesel applications, twin-scroll wastegated turbochargers provide a compelling and technically advantageous alternative.

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