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Mode-Dependent Effects of a Piggyback Throttle Controller on Torque and Power in a 1500 cc EFI Engine

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ABSTRACT

The rising adoption of aftermarket devices in the car modification industry has heightened interest in the piggyback throttle controller as an effective means of modifying throttle response without substituting the original ECU. Nonetheless, its impact on torque and power remains inadequately substantiated through controlled experimentation. This study experimentally assessed the impact of a 9-Drive piggyback throttle controller on the performance parameters of a 2011 Toyota Yaris 1500 cc EFI engine utilizing a chassis dynamometer. The car underwent testing under four conditions: no treatment, Standard mode, F1 mode, and ECO mode, with each condition replicated three times. The findings indicated that F1 mode generated the maximum average torque, attaining 177.13 Nm, which was 15.03 Nm greater than the untreated condition. Conversely, ECO mode yielded the highest average power at 98.60 HP, whereas Standard mode exhibited just negligible variations in both metrics. The data demonstrate that the controller did not produce a consistent performance enhancement across all modes, but instead altered the engine's output characteristics in a mode-dependent fashion. Under the current testing conditions, F1 mode exhibited a more pronounced torque-oriented response, while ECO mode demonstrated marginally greater power output. The findings indicate that a piggyback throttle controller can alter engine response characteristics, however its impact must be assessed in relation to the chosen mode and the particular performance metric under evaluation.

Keywords
piggyback throttle controller; throttle response; EFI engine; chassis dynamometer; torque and power

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INTRODUCTION

The automotive sector in Indonesia continues to develop alongside broader changes in vehicle technology, increasing adoption of electronically controlled powertrains, and growing user demand for improved drivability and performance-oriented customization [1], [2]. In the local context, experimental studies on aftermarket ignition-related modification also indicate continuing interest in practical vehicle-performance enhancement through relatively accessible electronic intervention [3]. This development has contributed to growing attention toward aftermarket devices that can modify vehicle response characteristics without requiring major mechanical changes or replacement of the original control system.

Among such devices, the Piggyback Throttle Controller has become increasingly attractive because it offers a relatively simple method for altering throttle-response behavior. Unlike full ECU replacement or full ECU remapping, this device operates as an auxiliary controller that modifies the signal sent from the accelerator pedal to the engine control unit (ECU). In modern EFI vehicles equipped with electronic throttle systems, pedal input is converted into an electrical signal, interpreted by the ECU, and then translated into throttle opening and fuel-delivery behavior. Because this process is signal-based, modifying the input signal can change throttle-response characteristics without physically altering the stock ECU or throttle body [4]–[7]. Supporting evidence from earlier local experimental work also shows that signal-level intervention in EFI-related sensor output can alter ECU fuel-control behavior and produce measurable increases in engine power and torque [5]. For this reason, piggyback throttle controllers are widely promoted as practical tools for creating more responsive or more progressive driving characteristics through selectable operating modes.

Previous studies suggest that piggyback-based and other aftermarket engine-control modifications can produce measurable changes in engine performance, although the magnitude and direction of those changes depend on the type of intervention applied. Zulfan et al. reported that the use of a piggyback fuel adjuster on a fuel-injection motorcycle increased both power and torque while also affecting injector opening behavior [4]. Purwanto et al. showed that modifying EFI-related sensor voltage can change ECU response and significantly increase power and torque output in a passenger vehicle platform [5]. Diep et al. further demonstrated that piggyback-ECU-based EFI remapping provides a relatively simple and flexible method for modifying engine-control behavior in spark-ignition engines [6]. Other experimental studies involving gas-pedal-based activation systems, bore-up modification, intake-air enhancement, and compression-ratio adjustment also demonstrate that torque and power are sensitive to changes in control strategy, intake conditions, and combustion-related parameters [8]–[11]. These findings are important because they confirm that aftermarket interventions can influence measurable engine-output parameters rather than merely altering subjective driver perception.

However, a clear research gap remains. Most recent studies have focused on piggyback fuel adjusters, piggyback ECUs, electronic throttle control modeling, or other forms of performance modification, whereas relatively limited evidence is available on the effect of a commercial piggyback throttle controller on the torque and power of an EFI passenger car under repeated chassis-dynamometer testing [4]–[7]. This distinction is important because a piggyback throttle controller primarily changes throttle-response behavior through signal manipulation, and its practical effect on engine output should therefore be validated experimentally rather than inferred solely from control theory or user impressions. In other words, a faster perceived throttle response does not automatically guarantee higher torque or power across all operating modes and test conditions.

Based on this gap, the present study investigates the effect of the 9-Drive Piggyback Throttle Controller on the torque and power characteristics of a 2011 Toyota Yaris 1500 cc EFI engine. The study addresses three research questions: (1) does the use of a piggyback throttle controller produce measurable changes in torque and power compared with the untreated condition; (2) which operating mode provides the most favorable torque and power characteristics; and (3) how should the observed results be interpreted in relation to aftermarket claims regarding throttle-response enhancement? By answering these questions through repeated dynamometer testing, this study is expected to contribute both practically, by providing objective evidence for users and practitioners, and academically, by strengthening the experimental literature on signal-based aftermarket engine-control devices in EFI vehicles.

METHOD

This study employed an experimental design to evaluate the effect of the 9-Drive Piggyback Throttle Controller on the torque and power characteristics of a 2011 Toyota Yaris 1500 cc EFI vehicle. The test vehicle was equipped with a 1497 cc engine, 75 × 84.7 mm bore and stroke, a 10.5:1 compression ratio, and a Sequential Fuel Injection (SFI) system. The experiment was conducted in the Vehicle Testing Laboratory of the Faculty of Engineering, Universitas Negeri Padang, using a chassis dynamometer to obtain direct measurements of engine output under controlled workshop conditions. Experimental automotive studies on engine-performance modification likewise rely on dynamometer-based testing because it allows torque and power to be measured under repeatable and instrumented conditions [12], [13].

Before testing, the vehicle was serviced to ensure that the engine remained in proper operating condition and that the observed differences could be attributed primarily to the treatment applied rather than to obvious mechanical irregularities. The experiment compared four operating conditions: (1) the untreated condition, (2) the Standard mode of the piggyback controller, (3) the F1 mode, displayed as 3.7 V, and (4) the ECO mode, displayed as 3.4 V. Each condition was tested three times, and the final results were expressed as the arithmetic mean of the triplicate runs. This repeated-measurement approach is consistent with recent experimental studies in automotive modification research, where direct comparison among treatment configurations is used to identify changes in torque and power output under different operating settings [14], [15].

The main research object and the device used in the experiment are presented in Figure 1. Figure 1(A) shows the 2011 Toyota Yaris, which was selected because it uses an electronic fuel injection system and an electronically controlled throttle architecture compatible with signal-based aftermarket devices. Figure 1(B) shows the 9-Drive Piggyback Throttle Controller, which was installed to modify throttle-response characteristics according to the selected operating mode. The controller was chosen because it provides multiple selectable modes, allowing comparison between a standard-like response and more aggressive or more progressive signal settings within the same vehicle platform. This kind of experimental configuration is methodologically appropriate for evaluating whether a control-related aftermarket intervention produces measurable differences in engine output [12], [15].

(A) (B)

Figure 1. Object of Research, (A) 2011 Toyota Yaris, (B) Piggyback Throttle Controller

The installation architecture of the device is illustrated in Figure 2. The system consists of five interconnected components: (A) accelerator pedal, (B) display unit, (C) piggyback module, (D) ECU, and (E) throttle controller. In this configuration, the accelerator pedal generates the input signal, which is intercepted and modified by the piggyback module before being transmitted to the ECU. The display unit is used to select the operating mode and monitor the controller status, while the ECU interprets the modified signal to regulate the throttle controller. Thus, Figure 2 clarifies that the piggyback controller does not replace the stock ECU, but alters the signal pathway between the accelerator input and the ECU-controlled throttle actuation. This installation scheme is central to the experimental logic of the study because the intervention is applied at the signal level rather than through internal engine modification.

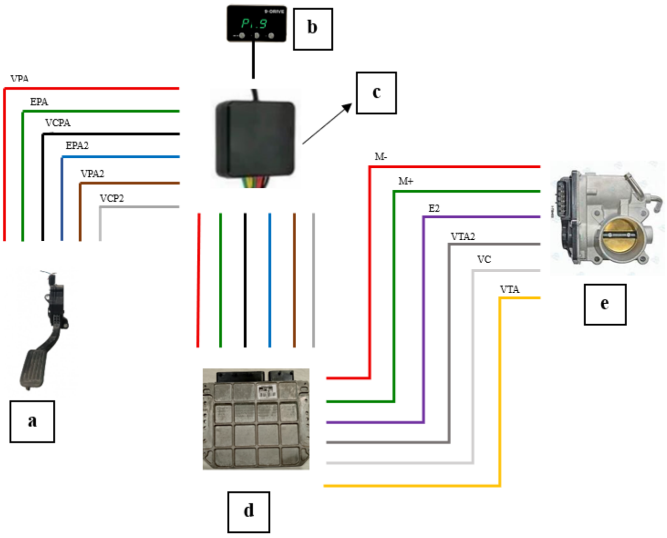

Figure 2. (A) Accelerator, (B) Display, (C) Module Piggyback, (D) ECU, (E) Throttle Controller.

The experimental framework is summarized in Figure 3. In this study, the independent variable was the controller mode, namely untreated, Standard, F1, and ECO, while the dependent variables were torque and power measured using the chassis dynamometer. The framework shows that the controller mode was expected to alter throttle-response behavior, which in turn could affect engine output. In methodological terms, Figure 3 serves as a simplified representation of the treatment–response relationship used in the experiment. This framing is consistent with experimental automotive studies that compare output variation across predefined control configurations [14], [16].

The piggyback controller was installed on the vehicle's accelerator-pedal socket, and each test mode was applied sequentially to the same vehicle to minimize inter-vehicle variability. During each run, the dynamometer recorded torque (Nm) and power (HP) as the primary variables. In addition, the study documented injection duration (ms) and maximum engine speed as supporting parameters to assist interpretation of the output changes observed under each mode. Because the principal objective of this study was to determine whether each controller mode produced measurable differences in torque and power, the data analysis was conducted descriptively by comparing the mean values obtained from the three repetitions in each treatment condition. No additional performance-prediction equation was introduced in the method section because the key output variables were obtained directly from the measuring instrument rather than estimated analytically. This approach keeps the method aligned with the actual design of the study and avoids introducing formulas that were not used in the analysis [13], [16], [17].

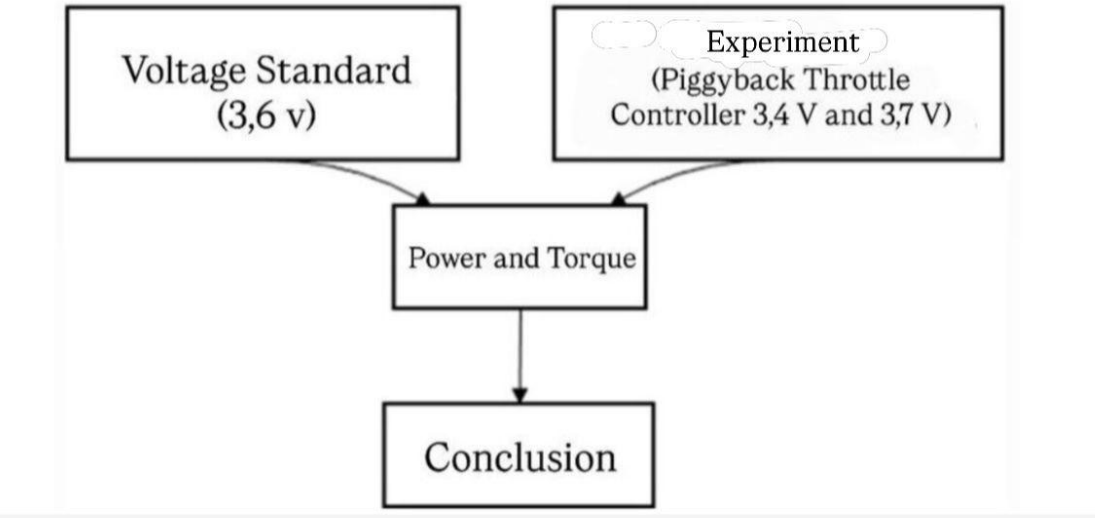

Figure 3. Conceptual Framework

Overall, the method was designed to isolate the effect of mode-based signal modification on the output characteristics of an EFI engine under repeated chassis-dynamometer testing. By combining a single-vehicle repeated-treatment design, a clearly defined electronic installation scheme, and direct measurement of torque and power, the study provides an experimental basis for evaluating whether a commercial piggyback throttle controller produces observable differences in engine-performance characteristics [12], [13].

RESULT AND DISCUSSION

Dyno Test Results for Torque and Power

The chassis dynamometer test was conducted to measure the torque and power output of the test vehicle under four operating conditions: no treatment, Standard mode, F1 mode, and ECO mode. Each condition was tested three times, and the average value was used as the basis for comparison. The complete results are presented in Table 1.

Table 1. Power and Torque Test Results

Conditions	Parameter	Test 1	Test 2	Test 3	Average
No Treatment	Torque (Nm)	165.8	157.4	163.1	162.1
	Power (HP)	98.2	97.8	97.5	97.83
Standard Mode	Torque (Nm)	162.3	175.4	153	163.57
	Power (HP)	97.6	97.5	99.2	98.1
Mode F1	Torque (Nm)	176.9	170.4	184.1	177.13
	Power (HP)	94.3	95.6	97.9	95.93
Mode ECO	Torque (Nm)	157.5	162.9	149.1	156.5
	Power (HP)	97.4	98.7	99.7	98.6

Source: Primary Data (2025)

As shown in Table 1, the untreated condition produced an average torque of 162.10 Nm and an average power of 97.83 HP. Under Standard mode, the average torque increased slightly to 163.57 Nm, while the average power also increased to 98.10 HP. The highest average torque was recorded in F1 mode, reaching 177.13 Nm, whereas the highest average power was obtained in ECO mode, with an average value of 98.60 HP. These results show that each piggyback mode generated a different output pattern for torque and power.

To clarify the changes relative to the untreated condition, the average values and their differences are summarized in Table 2.

Table 2. Comparison of Power and Torque Test Results

Conditions	Torque (Nm)	Torque Change	Power (HP)	Power Change
No Treatment	162.1	–	97.83	–
Standard Mode	163.57	+1.47 Nm (+0.91%)	98.10	+0.27 HP (+0.28%)
Mode F1	177.13	+15.03 Nm (+9.27%)	95.93	−1.90 HP (−1.94%)
Mode ECO	156.5	−5.60 Nm (−3.45%)	98.6	+0.77 HP (+0.79%)

Source: Primary Data (2025)

Based on Table 2, F1 mode produced the largest torque increase, with a gain of 15.03 Nm or 9.27% relative to the untreated condition. In contrast, this mode showed a reduction in power of 1.90 HP or 1.94%. Standard mode resulted in small increases in both torque and power, namely 1.47 Nm and 0.27 HP, respectively. Meanwhile, ECO mode produced the highest average power, increasing by 0.77 HP or 0.79%, but it also showed a decrease in torque of 5.60 Nm or 3.45% compared with the untreated condition.

The torque pattern across the four test conditions is illustrated in Figure 4. The figure shows that F1 mode yielded the highest average torque, followed by Standard mode, No Treatment, and ECO mode. This ordering is consistent with the values reported in Table 1 and Table 2, confirming that the greatest torque output was obtained when the controller operated in F1 mode.

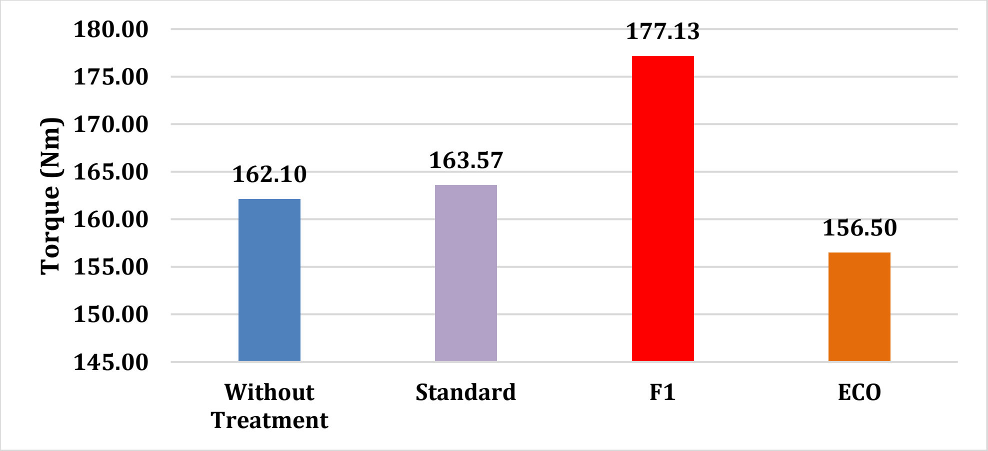

Figure 4. Torque Comparison Graph at Various Treatment Conditions

Likewise, the power distribution across the four treatment conditions is presented in Figure 5. The figure indicates that ECO mode produced the highest average power, followed by Standard mode, No Treatment, and F1 mode. This visual trend is also consistent with the numerical values in Table 1 and Table 2, where ECO mode recorded the highest power average and F1 mode the lowest.

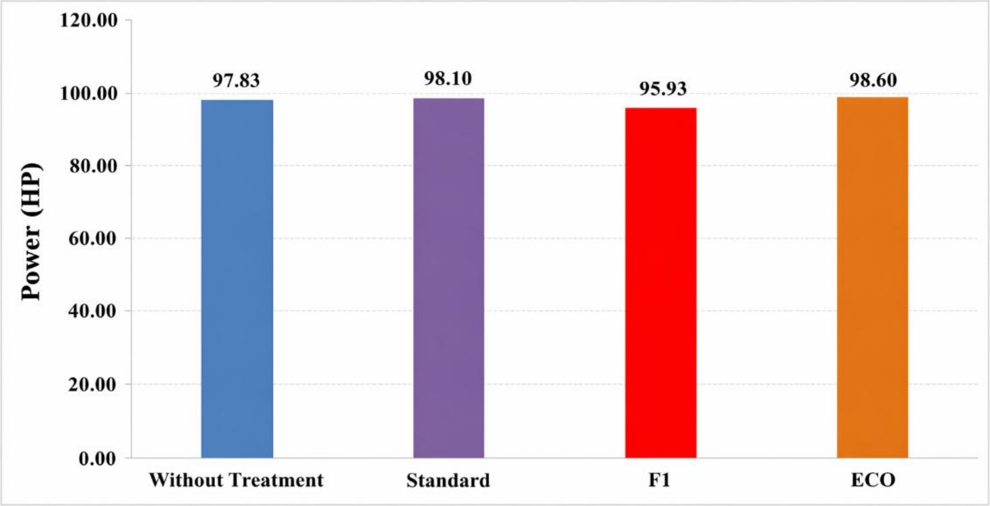

Figure 5. Power Comparison Graph at Different Treatment Conditions

Injection Duration and Maximum Rev Results

In addition to torque and power, the test also recorded injection duration under three operating ranges namely idle, middle, and high, together with the maximum rev indicator for each piggyback mode. The results are summarized in Table 3.

Table 3. Maximum Vlume and Rotation Injection Test Results

Mode	Idle (ms)	Middle (ms)	High (ms)	Maximum Rev (rpm)
Standard	0,007	0,064	0,081	162,4
F1 (3,7 V)	0,071	0,050	0,099	162,1
ECO (3,4 V)	0,066	0,061	0,075	162,2

Source: Primary Data (2025)

As presented in Table 3, the F1 mode recorded the highest injection value in the high operating condition, namely 0.099 ms, compared with 0.081 ms in Standard mode and 0.075 ms in ECO mode. At the idle condition, the recorded values were 0.007 ms for Standard, 0.071 ms for F1, and 0.066 ms for ECO. In the middle condition, the values were 0.064 ms, 0.050 ms, and 0.061 ms, respectively. The maximum rev values listed in the table were relatively close across all three modes, ranging from 162.1 to 162.4. Overall, the data in Table 3 show that the piggyback modes produced different injection-duration characteristics, with the highest value in the high operating condition occurring in F1 mode.

Discussion

The data in Table 1, Table 2, and Figure 4 indicate that the piggyback throttle controller had the most significant impact in F1 mode, yielding the highest average torque of 177.13 Nm, an enhancement of 15.03 Nm or 9.27% compared to the untreated condition. Simultaneously, Table 3 indicates that the F1 mode registered the greatest injection value under high operating conditions, specifically 0.099 ms. Collectively, these data indicate that the more assertive signal configuration in F1 mode heightened the effective throttle demand recognized by the ECU, possibly facilitating quicker throttle opening and an enhanced fuel-delivery response. This interpretation aligns with prior research on electronic throttle systems, indicating that variations in throttle-position tracking, actuator response, and control approach can substantially influence air-path behavior and vehicle dynamic response [6], [7], [18]–[22]. Similarly, local experimental investigations on control-related engine modifications demonstrate that torque and power can be significantly altered when the control pathway or operational responsiveness of the engine is adjusted [14], [15].

A distinct trend was noted in ECO mode. Table 1, Table 2, and Figure 5 indicate that ECO mode yielded the highest average power of 98.60 HP, while simultaneously exhibiting the lowest average torque of 156.50 Nm among the piggyback-assisted circumstances. Table 3 indicates that the injection value in ECO mode (0.075 ms) was inferior to that in F1 mode. This combination suggests that ECO mode provided a more gradual and less forceful throttle response, which did not optimize torque but still preserved a competitive power output. This explanation aligns with recent throttle-curve research indicating that altering throttle output does not inherently aim for maximal aggression; rather, it may be intended to enhance smoothness, response controllability, or energy efficiency qualities [23]. Research on electronic throttle control indicates that effective tuning seeks to optimize response speed, stability, and overshoot, rather than merely maximizing actuator opening expeditiously [18]–[22]. In this context, the ECO outcome in the current study may be understood as a more moderated output strategy that promotes smoother reaction behavior while maintaining power at a reasonably elevated level. This study did not directly measure AFR, BSFC, or combustion efficiency; hence, any analysis should be approached with caution and not extrapolated beyond the recorded torque–power data.

The Standard mode yielded only slight modifications, with torque rising to 163.57 Nm and power escalating to 98.10 HP, as illustrated in Table 2. This indicates that the Standard setting functioned as a moderate recalibration rather than a forceful intervention. From a pragmatic perspective, this is significant as it suggests that not all piggyback modes produce identical levels of output variation. Comparable mode- or configuration-dependent outcomes have also been documented in other experimental modification investigations. Local dynamometer studies indicate that moderate adjustments can yield more balanced performance improvements compared to more aggressive setups, contingent upon whether the objective is torque, power, or both [10], [11], [14], [17], [24]. This is particularly pertinent to the current study as the ranking of modes varies between Figure 4 and Figure 5: the mode optimal for torque is not the mode optimal for power. Thus, the results reinforce the idea that engine-performance optimization is objective-specific, meaning that the preferred setting depends on whether the user prioritizes acceleration feel, peak output, or balanced drivability.

Nevertheless, the F1 mode data indicate that the augmentation in torque was correlated with a reduction in average power to 95.93 HP, which is 1.90 HP lower than the untreated condition, as illustrated in Table 2 and Figure 5. This signifies that the impact of the piggyback controller was inconsistent across performance metrics. The F1 setting seems to prioritize enhanced torque delivery at the expense of a marginal decrease in peak power, rather than enhancing both torque and power concurrently. A like trend has been observed in other research concerning engine control and fuel supply modifications, when improvements in one performance metric do not consistently correlate with enhancements in another. Aftermarket ECU tests indicate that enhanced fuel delivery or modified control mapping can augment torque and power, albeit frequently at the expense of efficiency or emissions [25]. Similarly, programmable-ECU testing with variations in ignition timing has demonstrated that modifications in control approach can produce very minor but directionally significant differences in power and torque results [26]. Related research on fuel-injected engine optimization indicates that modifications in ECU-based control might enhance specific output characteristics while compromising other performance metrics [27]. Consequently, the current data suggest that the piggyback throttle controller should be regarded mostly as a device that modifies engine reaction characteristics, rather than as a mechanism that ensures consistent enhancement of all performance metrics across all modes.

The supporting variables in Table 3 serve as a crucial interpretive link between the treatment administered and the results documented in Table 1 and Table 2. While the study did not assess complete combustion characteristics, the variations in injection length across modes indicate that the piggyback controller affected more than merely the apparent pedal response. The data suggest that signal alteration at the throttle-input stage can transmit through the control system and influence fuel delivery behavior. This analysis aligns with other piggyback and ECU-based research, indicating that alterations in signal routes or ECU control logic might influence injector performance, combustion conditions, and subsequently torque–power output [4], [5], [24]–[27]. The current findings reinforce the notion that a commercial piggyback throttle controller should not be regarded solely as a "driver-feel accessory," but rather as a technology that can effect quantifiable alterations in engine-output parameters during controlled testing. Nonetheless, the extent of change seen in this study, particularly regarding power, was comparatively minor in both Standard and ECO modes. Consequently, the practical implications of these discrepancies must be taken with caution, especially since no inferential statistical analysis was conducted on the current dataset.

This study has two primary consequences from a practical standpoint. Initially, it offers an impartial foundation for mode selection. Should the user prioritize enhanced torque delivery and a more vigorous acceleration experience, the F1 mode emerges as the most appropriate choice, as indicated by Figure 4 and Table 2. If the customer want increased power with a more progressive throttle response, ECO mode may be preferable, although Standard mode provides the optimal mix between the two. Secondly, the research suggests that commercial throttle-controller configurations should be determined by empirical output characteristics rather than merely subjective driving perceptions. This study provides experimental proof that signal-based aftermarket control devices can modify measured torque and power characteristics without altering the standard ECU or internal engine components. This builds from previous research with piggyback fuel adjusters, ECU remapping, programmable ECUs, and throttle-curve manipulation by demonstrating that a commercial throttle controller can provide mode-dependent output variations on an EFI passenger car platform [4]–[7], [23]–[27]. This study underscores the necessity for comprehensive follow-up analyses concerning air-fuel ratio, fuel consumption, emissions, rpm-resolved output curves, and inferential statistics, to facilitate a more confident interpretation of the mechanisms underlying the observed differences and enhance generalizability.

CONCLUSION

This study demonstrates that the 9-Drive Piggyback Throttle Controller did not produce a uniform increase in all engine-output parameters, but instead altered the performance character of the 2011 Toyota Yaris 1500 cc EFI engine in a mode-dependent manner. Under the present test conditions, F1 mode was associated with the strongest torque-oriented response, whereas ECO mode was associated with the highest average power, and Standard mode produced only modest changes relative to the untreated condition. These findings indicate that the principal effect of the controller lies in reshaping throttle-response and output behavior rather than delivering a consistent overall performance gain across all modes. Accordingly, the practical value of the device is not that it universally improves engine performance, but that it allows different output characteristics to be selected according to the intended driving preference.

The findings of this study should be interpreted within the limits of the experimental design. The analysis was based on one vehicle, one piggyback throttle controller, and three repetitions for each condition, with no inferential statistical testing applied. In addition, supporting variables such as air–fuel ratio, fuel consumption, exhaust emissions, and detailed environmental test conditions were not included, so the mechanism behind the observed differences cannot yet be explained comprehensively. Future studies should therefore involve a larger number of repetitions, multiple controller brands or vehicle platforms, and additional performance and combustion-related variables so that the effect of piggyback throttle controllers can be evaluated with greater statistical strength and broader practical relevance.

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