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Research Article

Investigation Into The Correlation Between Intake Air Temperature And Fuel Consumption In Chevrolet Cobalt Vehicles Equipped With A 1.5-Litre B15d2 Engine Under Winter Operational Conditions

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N.I. Otabayev
Candidate of Technical Sciences, Associate Professor, Fergana State Technical University, Fergana, Uzbekistan

A.B. Luqmonjonov
Master's Student, Fergana State Technical University, Fergana, Uzbekistan

ABSTRACT

This research is specifically aimed at determining and evaluating the precise correlation that exists between the intake air temperature entering the engine and the subsequent fuel consumption rates of Chevrolet Cobalt passenger cars during winter operational periods. Over the course of this investigation, the multi-faceted effects of ambient environmental temperatures, along with the thermal regime of the internal combustion engine, on overall fuel economy were systematically examined utilizing comprehensive analytical methods and mathematical modelling techniques. The empirical and theoretical outcomes obtained demonstrate that under low-temperature conditions, fuel consumption increases significantly and substantially, which is primarily driven by the extended engine warm-up durations required and the inherently increased density of the cold intake air.

KEYWORDS

Chevrolet Cobalt, winter operation, engine thermal regime, fuel consumption, internal combustion engine, ambient temperature driving.

INTRODUCTION

Fuel consumption is fundamentally established as a complex function resulting from the continuous interaction between the engine operating mode, ambient environmental conditions, and various operational factors. From a theoretical perspective, the fuel economy of an internal combustion engine is directly and intrinsically linked to its thermal balance and the efficiency of energy transformation throughout the thermodynamic cycle. In particular, the temperature of the intake air entering the cylinders, alongside the temperature of the engine coolant, exerts a substantial and measurable influence on the overall intensity of the combustion process, the completeness of fuel vaporization and subsequent oxidation, and the ultimate thermal efficiency of the power unit. As the operating temperature drops, the chemical kinetics and physical mechanisms of the combustion process become increasingly problematic, which systematically leads to an elevation in the specific fuel consumption of the vehicle.

In prevailing theoretical models, engine operating conditions are predominantly characterized on the basis of stationary, idealized, and steady-state parameters. Under these simplified analytical assumptions, the temperatures of both the intake air and the cooling fluid are conventionally treated as fixed, strictly predetermined values. However, under real-world operational conditions — most notably during winter periods — these parameters exhibit a highly dynamic and variable character across both temporal and spatial dimensions. This variability inevitably induces non-stationarity and instability in the internal engine processes, thereby introducing severe uncertainties into the precise determination and prediction of actual fuel consumption rates. From this perspective, a critical need arises during the winter exploitation of motor vehicles to develop advanced analytical approaches capable of incorporating the continuous fluctuations of these thermal regimes into theoretical fuel consumption assessments [1]. The implementation of such comprehensive approaches serves as a foundation for constructing high-fidelity mathematical models that closely approximate real-world engine operations, facilitating deep analyses of transient thermal processes and enabling the formulation of scientifically grounded methodologies to enhance vehicle fuel economy.

The primary objective of this research is to identify, evaluate, and formulate the underlying regularities governing the variations in engine fuel economy during winter conditions, and to utilize these insights to enhance the overall efficiency of fuel consumption in Chevrolet Cobalt passenger cars equipped with a 1.5-litre engine. This investigation relies on a combination of rigorous theoretical evaluations and the acquisition of empirical measurement data. The resulting operational indicators are highly dependent upon a multi-faceted matrix of transport configurations, road infrastructures, and natural bioclimatic or weather-related environments. Ultimately, these continuous variations in external operational conditions exert a profound and determinative impact on the output performance characteristics of the vehicles, most notably manifested in their fluctuating rates of fuel consumption [2].

Methodology

In terms of the natural bioclimatic and environmental parameters governing motor vehicle exploitation, the territory of the Republic of Uzbekistan is systematically classified into five distinct geographical zones:

– Desert and semi-desert regions, encompassing the Kyzylkum desert, Bukhara, Navoiy, and the Republic of Karakalpakstan. These areas are characterized by a severely dry climate, high summer temperatures, and harsh winter conditions, with absolute minimum temperatures falling within the range of −15 °C to −20 °C.

– Plains and valley regions, including Tashkent, Samarkand, Jizzakh, Syrdarya, and the Amu Darya valley. This zone experiences a sharply continental climate characterized by cold winters and hot, arid summers, with minimum temperature fluctuations dropping down to −10 °C to −15 °C.

– Mountain and foothill regions, comprising the Hissar and Zarafshon ranges, alongside the Chimgan territory. These zones are defined by a vertical climatic zonation where temperatures decrease progressively with increasing altitude and snow cover persists for extended durations, experiencing minimum temperatures between −15 °C and −25 °C.

– Southern warm regions, spanning Surxondaryo, Termez, and the southern parts of the Qashqadaryo region. This zone is characterized by a relatively mild winter period, with minimum environmental temperatures ranging from −5 °C to −10 °C.

– Water basins and humid zones, located predominantly along the immediate banks of the Amu Darya and Syrdarya rivers. These areas feature a higher relative humidity and comparatively mild winter microclimates, with minimum temperatures dropping to between −5 °C and −10 °C.

When performing a detailed spatial-temporal analysis of the natural climatic factors across Uzbekistan, it is evident that severe cold-weather conditions predominantly affect the mountainous and foothill zones, as well as the northern and western sectors of the desert territories. These low-temperature regions account for approximately 15% to 20% of the total land area of the republic. In the mountain and foothill regions — specifically across the Hissar, Zarafshon, and Chimgan mountains — the absolute minimum winter temperatures plunge to between −15 °C and −25 °C, while the average seasonal temperature hovers around −5 °C to −10 °C. Concurrently, in the northern and western expanses of the desert regions, most notably within the Bukhara, Navoiy, and Karakalpakstan desert zones, the winter season is highly rigorous, with minimum values recorded between −15 °C and −20 °C and mean temperatures fluctuating around −2 °C to −5 °C. Consequently, these sub-zero climatic zones impose highly rigorous and extreme operational demands on vehicular performance during the winter period, highlighting the critical importance of localized thermal forecasting when planning transportation networks, agricultural logistics, and energy infrastructure.

During the practical exploitation of Chevrolet Cobalt passenger cars, ambient air temperatures shifting below the 0 °C threshold trigger the icing of road surfaces and a sharp reduction in the adhesion coefficient between the vehicle tyres and the pavement, thereby exerting a determinative influence on driving dynamics and kinematic parameters. Based on the empirical findings of this research, the implementation of the following engineering and operational interventions is highly effective for enhancing vehicular performance in cold weather:

– Utilizing specialized cold-start assistive devices and thermal additives that facilitate easier engine ignition under sub-zero conditions.

– Allowing the power unit to reach its optimal thermal operating threshold prior to deploying the vehicle on its scheduled route.

– Precision management of the stoichiometric air-fuel ratio through advanced electronic fuel injection system adaptations.

– Maintaining the structural temperatures of transmission assemblies and internal gearboxes within their ideal functional ranges.

Furthermore, the overall degradation of fuel efficiency observed during the winter season is multi-causal, being explicitly tied to the increased density of cold air, an escalation in tyre rolling resistance, and substantial structural temperature variations across vital engine components.

Under winter operational conditions, the physical characteristics of cold air cause an increase in the aerodynamic drag forces acting against the vehicle body, while simultaneously aggravating other mechanical resistances opposing tyre rotation and motion. These continuous alterations in the thermal state of key automotive systems — namely the transmission, cooling, and lubrication circuits — directly influence the quality and mass composition of the air-fuel mixture, a factor that is fundamentally linked to the overall fuel economy of the power unit [3]. Under these low-temperature regimes, the actual fuel consumption of the Chevrolet Cobalt passenger car, which is powered by a 1.5-litre B15D2 electronic fuel injection engine, increases by approximately 21% to 22%. This total elevation in energy consumption is primarily accounted for by a 12% increase in tyre rolling resistance and an 8% expansion in aerodynamic drag forces [4]. Additionally, the deviation of the intake air temperature away from its optimal thermal design point causes the electronic fuel injection system to adjust its mapping, which introduces an additional 1.5% increase in fuel consumption. Therefore, to preserve the inherent fuel efficiency of the Cobalt vehicle under low-temperature conditions, it is vital to properly prepare the engine's thermal state prior to operation and to strictly control the air-fuel mixture parameters via targeted electronic injector management.

Results And Discussion

The fuel economy of a motor vehicle is significantly and measurably influenced by a diverse matrix of interrelated factors that collectively characterize its real-world operational environment:

– The specific driving cycle, encompassing parameters such as average and peak velocity, total route length, and continuous driving duration.

– The technical processes involved in the initial starting and subsequent warm-up phases of both the power unit and the transmission assembly.

– The inherent baseline technical characteristics and structural specifications of a new vehicle.

– Environmental and ambient meteorological conditions.

– The current maintenance status, technical wear level, and the individual operational skill or driving habits of the operator.

Among these multi-faceted variables, the prevailing natural bioclimatic and atmospheric conditions are of paramount importance, exerting a profound and determinative impact on the continuous fluctuations observed in actual fuel consumption rates.

One of the primary physical mechanisms driving the escalation of fuel consumption during cold-weather exploitation is the internal thermal regime of the power unit. Within the specific architecture of the Chevrolet Cobalt 1.5-litre B15D2 engine, this complex thermal state is precisely characterized and monitored through the following critical parameters:

– The temperature of the intake air and the subsequently formed air-fuel charge entering the induction manifold.

– The temperature of the liquid engine coolant circulating within the cylinder block jackets and the cylinder head passages.

– The mean temperature of the lubricating engine oil contained within the oil pan crankcase.

Any deviation or continuous variation across these specific thermal parameters directly alters the thermodynamic efficiency of the combustion process, thereby exerting a immediate and quantifiable effect on the overall fuel economy of the vehicle.

Under the dry, sharply continental climatic conditions characteristic of the winter season in the Republic of Uzbekistan, ambient air temperatures frequently drop into the rigorous range of −10 °C to −20 °C. Under these severe sub-zero conditions, empirical evaluations demonstrate that the temperature of the intake air entering the induction system of the Chevrolet Cobalt 1.5 L B15D2 electronic fuel injection engine remains substantially higher than the surrounding ambient environmental temperature. For instance, when operating the vehicle in an ambient environment stabilized at −15 °C, the localized air temperature within the under-bonnet space can rapidly elevate to a range between 20 °C and 25 °C. Concurrently, systematic measurements have confirmed that the steady-state thermal regime of the under-bonnet microclimate typically remains 1.5 to 2 times higher than the immediate external atmospheric temperature.

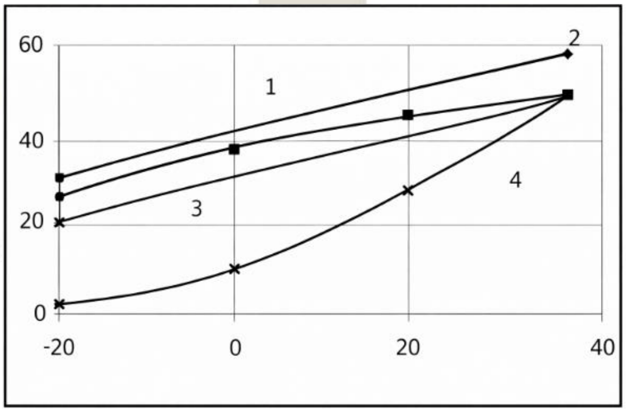

Figure 1. Dynamic variations in the under-bonnet air temperature profiles of passenger vehicles

This elevated under-bonnet thermal state plays a critical role in governing the operational stability, fuel injection mapping, and macro-structural atomization of the fuel spray within electronic injection engines. Even when the fresh intake air drawn into the induction manifold from the external environment is profoundly cold, the high ambient heat radiating within the enclosed under-bonnet compartment typically maintains the localized intake temperature at a stable range of 10 °C to 20 °C, which effectively facilitates the rapid break-up of liquid fuel into extremely fine, readily vaporized droplets. Conversely, the liquid gasoline reaching the fuel injector rail is delivered via the fuel delivery pump at a highly constrained temperature of approximately 5 °C to 15 °C; this low fuel temperature inherently retards the rate of droplets vaporization and significantly complicates the initial cold-start sequence of the power unit. Although the mechanical operation and internal friction of the electric fuel pump generate a nominal amount of thermal energy, the actual temperature of the gasoline arriving at the rail during winter conditions remains limited to approximately 0 °C to 5 °C. Meanwhile, the bulk fuel stored within the main fuel tank remains virtually in equilibrium with the external environment, dropping to temperatures as low as −30 °C during severe winter periods, which systematically degrades the initial chemical reactivity and response characteristics of the engine during start-up operations [5].

Ultimately, the comprehensive thermal regime governing the entire induction and air-supply system of the internal combustion engine is scientifically quantified and modeled o

$$t_{cp} = \sum_{i=1}^{n} t_y \delta_{yi} - \frac{t_k - t_n}{m_\partial \tau_\partial} \qquad (1)$$

where:

t_y is the stabilized temperature of the intake air entering the internal combustion engine during vehicle operation in the \$i\$-th gear, measured in degrees Celsius (°C).

δ_{yi} represents the proportional share or fractional duration of the total operation time spent driving in the respective i-th gear.

t_k, t_n denote the initial and final thermal states (temperatures) of the functional powertrain assemblies, respectively, expressed in degrees Celsius (°C).

m_∂-indicates the continuous warming-up rate of the system components during active vehicle motion, quantified in reciprocal minutes (min^{-1}).

τ_∂ signifies the total duration of uninterrupted vehicle motion or continuous driving, measured in minutes (min).

Any significant deviation of the intake air temperature from its design-optimal value systematically leads to a measurable degradation of the overall vehicular fuel efficiency. In Chevrolet Cobalt passenger cars operated under winter conditions, sharp drops in the ambient thermal regime cause the incoming air-fuel charge to become excessively dense, which substantially complicates the initial engine ignition and cold-start sequence. Furthermore, empirical observations indicate that under specific ambient environmental conditions characterized by an initial temperature of 7.5 °C, the localized temperature of the air-flow control valve can drop rapidly to as low as −14 °C within a brief duration of just 2 minutes. This localized physical phenomenon induces rapid over-cooling of adjacent structural engine components, triggering a pronounced temporary decline in the subsequent thermal and fuel efficiency of the power unit.

The electronic fuel injection engine of the Chevrolet Cobalt — specifically the B15D2 powertrain generation — is characterized by a 1.5-litre displacement (exactly 1485 cm3), featuring a 4-cylinder, 16-valve configuration integrated with an advanced multipoint port fuel injection architecture. This specific internal combustion engine layout generates a maximum output power of 106 horsepower alongside a peak rotational torque of approximately 141 Nm. Under rigorous and extreme natural bioclimatic conditions, a sudden drop in both the temperature and static pressure of the fresh intake air substantially modifies the mass density of the incoming air-fuel mixture, which subsequently exerts an adverse impact on the spray atomization efficiency of the fuel injectors and the overall chemical kinetics of the combustion process. To ensure maximum fuel economy and optimal functional performance of the electronic injection B15D2 engine, the system relies on the following strictly regulated thermal boundaries:

— The intake air temperature must ideally be stabilized within the range of 25 °C to 35 °C.

— The delivered fuel temperature at the injection rail must be maintained between 15 °C and 20 °C.

— The structural wall temperature of the intake manifold must be continuously monitored and dynamic managed by the electronic control unit.

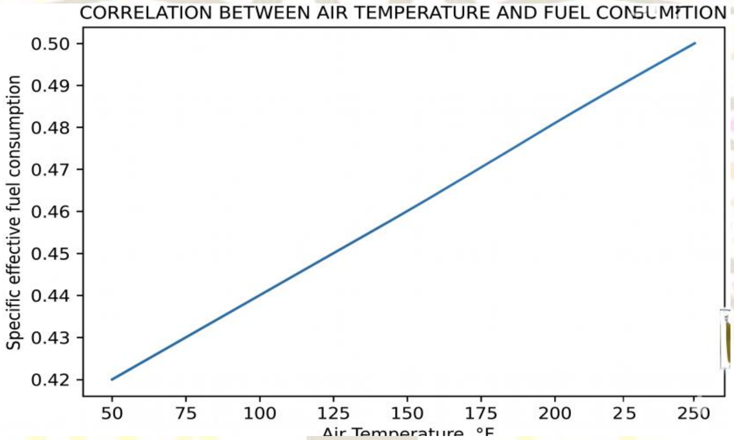

Figure 2. Graphic representation of the direct influence of induction air temperature variations on specific fuel consumption rates

In the B15D2 electronic fuel injection engine of the Chevrolet Cobalt (2025 generation), the intake air temperature exerts a complex, dual-natured influence on overall engine performance and combustion characteristics. Specifically, an increase in the intake air temperature within the range of 15 °C to 60 °C results in a corresponding reduction of the excess air coefficient (α) by approximately 8% to 10%. This physical shift subsequently causes a relative enrichment of the air-fuel mixture, which can lead to a measurable increase in overall fuel consumption by 4% to 5%.

Simultaneously, however, this localized heating of the intake charge significantly enhances the structural atomization and subsequent combustion quality of the fuel spray. This thermal effect:

— Substantially reduces the unwanted deposition and separation of a liquid fuel film along the intake manifold walls.

— Facilitates a highly efficient, rapid vaporization of the gasoline droplets within the dynamic stream of the combustible mixture.

Empirical evaluations indicate that as the intake air temperature entering the Cobalt B15D2 power unit varies dynamically from −20 °C up to 60 °C, the excess air coefficient shifts steadily from approximately 0.97 to 1.08. Consequently, the temperature of the induction air maintains a highly intricate, multi-faceted, and dual-effect relationship with both the thermodynamic efficiency of the engine and its actual rate of fuel consumption.

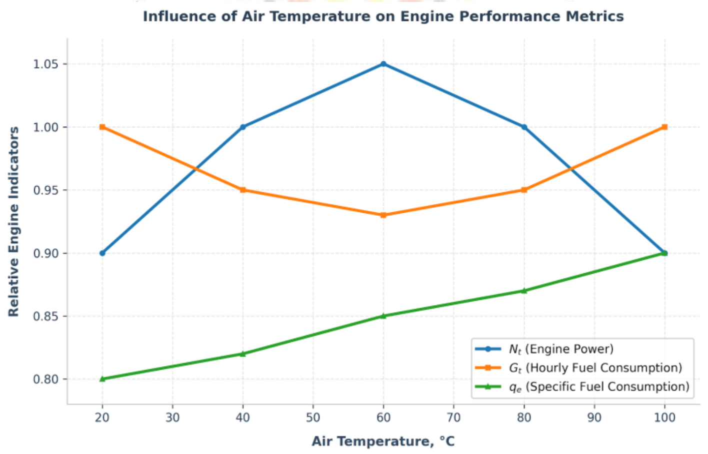

Figure 3. Graphical evaluation of the correlation between induction air temperature profiles and the functional performance parameters of the Cobalt 2025 (B15D2 electronic fuel injection engine)

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Furthermore, empirical evaluations indicate that as the intake air temperature entering the B15D2 power unit varies dynamically from −20 °C up to 60 °C, the excess air coefficient shifts steadily from approximately 0.97 to 1.08. Consequently, the temperature of the induction air maintains a highly intricate, multi-faceted, and dual-effect relationship with both the thermodynamic efficiency of the engine and its actual rate of fuel consumption, which can be categorized as follows:

— It alters the mass density of the incoming air charge, thereby directly shifting the stoichiometric balance of the fuel injection mapping.

— It dictates the chemical kinetics and vaporization rate of the fuel spray inside the cylinders, which ultimately impacts the complete thermal energy release.

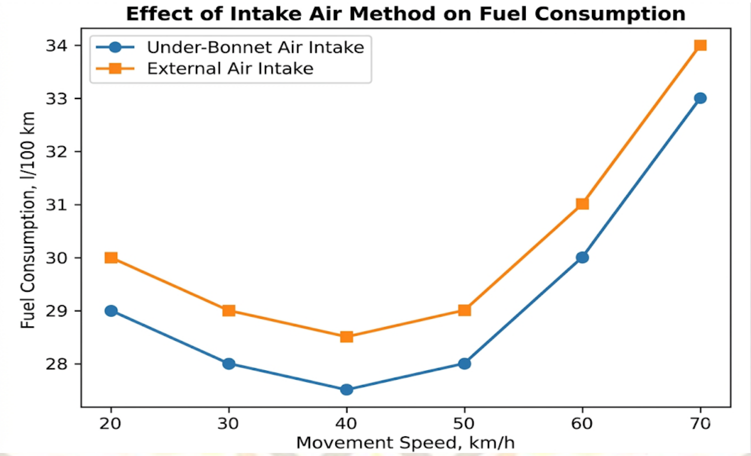

Figure 4. Economic performance indicators and fuel efficiency metrics of the Chevrolet Cobalt 2025 passenger car equipped with a B15D2 engine

The engine coolant temperature alongside the intake air temperature directly dictates the overall fuel efficiency and the subsequent exhaust gas emission composition — specifically Carbon Monoxide (CO), Hydrocarbons (HC), and Nitrogen Oxides (NO_x) — of the Chevrolet Cobalt 2025 B15D2 electronic fuel injection engine. As the operational mode of the power unit shifts dynamically, vital internal parameters such as the crankshaft rotational speed (n), the brake torque (M_e), and the effective brake power (N_e) vary concurrently, which exerts a profound and determinative influence on the overall combustion efficiency of the air-fuel charge and the resulting ecological characteristics of the vehicle.

Conclusion

The dynamic operation of the Chevrolet Cobalt 2025 passenger car's B15D2 electronic fuel injection engine under rigorous and extreme natural bioclimatic conditions demonstrates a substantial and measurable impact on both fuel economy and exhaust emission composition. The thermal states governed by the intake air temperature, the delivered fuel temperature, and the circulating engine coolant temperature are intrinsically and directly linked to the fundamental operating parameters of the engine, namely:

– The crankshaft rotational speed (n).

– The effective brake torque (Me).

– The brake specific power output (Ne).

To achieve the maximum thermodynamic efficiency of the B15D2 powertrain system, the internal operating environment must be maintained within the following scientifically determined optimal parameters:

– The intake air temperature entering the manifold should be stabilized between 25 °C and 35 °C.

– The delivered fuel temperature at the injector rail must be kept within the range of 15 °C to 20 °C.

– The structural wall temperature of the intake manifold channels must be regulated at approximately 90 °C to 110 °C.

Strict adherence to these highly specific thermal thresholds ensures the complete and high-efficiency chemical oxidation of the air-fuel mixture, allows the vehicle to maintain its fuel consumption rates at a minimal design level, and effectively optimizes the total environmental and exhaust emission profile.

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