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Research Article

CFM56-7B Electronic Engine Control System Performance During Ground Run-Up Test

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ABSTRACT

The performance of the Electronic Engine Control (EEC) system is essential for ensuring safe aircraft operation following engine maintenance. This study evaluates the EEC performance of a CFM56-7B turbofan engine during an on-aircraft Engine Ground Run-Up (EGR) test conducted after engine replacement on a Boeing 737-800 Next Generation aircraft. The test was performed under controlled ground conditions in accordance with the Aircraft Maintenance Manual, and key EEC-controlled parameters—including fan speed (N1), compressor speed (N2), exhaust gas temperature (EGT), fuel flow, lubrication parameters, and engine vibration—were recorded using the aircraft's built-in sensor system. The results indicate that all monitored parameters remained within manufacturer-specified acceptance limits during engine start, idle, Maximum Power Assurance, and static take-off power conditions, demonstrating stable EEC regulation under both transient and steady-state operation. Fuel consumption during the EGR procedure was consistent with the applied power settings, reflecting appropriate fuel scheduling. Comparison with representative test-cell–based studies show similar performance trends, with expected differences in thermal behavior attributable to on-wing installation effects during ground operation. Overall, the findings confirm that on-aircraft EGR testing provides an effective and operationally representative approach for post-maintenance verification of EEC performance, bridging the gap between test-cell evaluations and actual aircraft operation.

Keywords:
Electronic Engine Control;
turbofan engine;
ground run-up test;
engine performance.

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1. INTRODUCTION

The CFM56-7B engine is a high-bypass turbofan that has been extensively deployed as the primary powerplant for narrow-body commercial aircraft, particularly the Boeing 737-800 Next Generation (NG) fleet [1]. Its widespread adoption is driven by a combination of robust design, high operational reliability, favorable fuel efficiency, and relatively low maintenance costs, making it a benchmark engine in commercial aviation operations [2]. As a developed variant of the CFM56 engine family, the CFM56-7B is designed to deliver improved thrust capability and operational efficiency while maintaining strict safety margins under a wide range of operating conditions [3]. Given its critical role in airline operations, ensuring that the engine performs within manufacturer-specified limits after maintenance activities is essential for sustaining aircraft reliability, safety, and dispatch readiness [4].

A critical component governing the operation of the CFM56-7B engine is the Electronic Engine Control (EEC), a fully digital control system responsible for regulating key engine parameters, including fuel flow, fan speed (N1), compressor speed (N2), exhaust gas temperature (EGT), and lubrication conditions [5]. By continuously processing real-time sensor inputs, the EEC optimizes engine performance and ensures that all operating parameters remain within the stringent limits prescribed by the manufacturer across all phases of engine operation [6]. In addition to enhancing engine responsiveness and reducing pilot workload through automated control functions, the EEC provides essential monitoring and diagnostic capabilities that support maintenance decision-making and operational safety [7]. Consequently, the performance of the EEC plays a central role in determining engine reliability, particularly following maintenance actions that may affect system configuration or sensor integrity.

Following engine replacement or major maintenance activities, it is essential to conduct comprehensive performance checks to verify that the newly installed engine operates correctly and meets all safety and reliability requirements before returning the aircraft to service [8]. Post-maintenance conditions may introduce potential issues such as abnormal engine start behavior, excessive vibration, unstable idle operation, or deviations in critical parameters including exhaust gas temperature, fuel flow, oil pressure, and rotational speeds (N1 and N2) [9]. In addition, maintenance-induced faults related to fuel control systems, sensor calibration, or leaks within fuel and lubrication circuits can adversely affect engine performance if not detected at an early stage [10]. These risks underscore the necessity of reliable post-installation testing procedures that are capable of identifying anomalies and ensuring that the Electronic Engine Control system governs engine operation as intended under operational conditions.

In practice, the performance of the CFM56-7B engine is often evaluated through flight testing, as this approach provides accurate insights into engine behavior under real operational conditions across various flight phases, including thrust generation, fuel consumption, and exhaust gas temperature [11]. However, conducting flight tests immediately after engine replacement or major maintenance introduces considerable safety and operational risks, as undetected malfunctions or control anomalies may lead to in-flight failures with potentially severe consequences. In addition to safety concerns, flight testing at this stage is associated with high operational costs and limited opportunities for controlled troubleshooting. These limitations highlight the need for alternative verification methods that can reliably assess engine and Electronic Engine Control performance prior to flight release.

Previous research on turbofan engine performance has predominantly relied on test-cell–based evaluations, where engines are assessed in controlled environments prior to installation on the aircraft [12]. Such studies have provided valuable insights into engine characteristics, including emissions behavior, thermal performance, and compressor–turbine interactions under standardized conditions. For instance, Turgut et al. investigated turbofan performance using emission measurements in off-wing test-cell configurations, while Yang et al. examined ground test modeling through high-temperature and high-pressure simulations [12][13]. Although these approaches contribute significantly to the understanding of turbofan engine behavior, they do not fully capture the effects of on-aircraft installation, where airframe interactions, integrated sensor networks, and real-time control system responses can influence overall engine performance.

Despite the extensive body of research on turbofan engine performance and control systems, limited attention has been directed toward evaluating the Electronic Engine Control (EEC) performance of the CFM56-7B engine during on-aircraft Engine Ground Run-Up (EGR) testing, particularly following engine replacement [12][13]. Most existing studies focus on test-cell environments or simulation-based analyses, leaving a gap in understanding how the EEC governs real-time engine parameters under actual operational ground conditions, where installation effects, sensor integration, and system interactions play a critical role. Addressing this gap is important for improving post-maintenance verification procedures and enhancing confidence in engine readiness prior to flight operations.

Accordingly, this study contributes by: (1) presenting empirical EGR data collected directly from a Boeing 737-800NG aircraft following the replacement of engine No. 1; (2) evaluating the accuracy and stability of EEC regulation for critical parameters including N1, N2, exhaust gas temperature, fuel flow, and oil pressure; and (3) integrating operational findings into a diagnostic perspective that supports predictive maintenance and post-maintenance verification under real on-wing conditions.

Engine Ground Run-Up (EGR) testing represents a safer and more practical alternative for post-maintenance verification prior to flight release. Conducted under controlled ground conditions, the EGR method allows engine power to be progressively increased while critical parameters—such as vibration, fuel flow, oil pressure, and exhaust gas temperature—are closely monitored without exposing the aircraft or crew to the risks associated with early flight testing [13]. As a standardized post-maintenance procedure, EGR testing is specifically intended to verify both engine health and the functional performance of the Electronic Engine Control system by assessing its ability to regulate key parameters across different power settings in accordance with manufacturer requirements [14][15][16]. Through this approach, potential anomalies can be identified and corrected at an early stage, thereby reducing safety hazards and operational costs while ensuring compliance with established certification and maintenance standards [17].

Accordingly, this study investigates the performance of the Electronic Engine Control system of a CFM56-7B engine during on-aircraft Engine Ground Run-Up testing conducted after the replacement of engine No. 1. By integrating empirical EGR test data with established technical references, the study aims to assess the effectiveness of the EEC in managing engine operation under controlled ground conditions and to support best practices in post-maintenance verification and predictive maintenance frameworks [18]. The scope of the investigation is limited to parameters directly governed by the EEC, including rotational speeds, exhaust gas temperature, fuel flow, lubrication behavior, and vibration, providing a focused and operationally relevant assessment prior to flight release.

2. RESEARCH METHODS

2.1 Test Object and Aircraft Configuration

The object of this study is a CFM56-7B turbofan engine installed on a Boeing 737-800 Next Generation (NG) aircraft following the replacement of engine No. 1. The investigation focuses on evaluating the performance of the Electronic Engine Control (EEC) system during a post-maintenance Engine Ground Run-Up (EGR) test conducted under on-aircraft conditions.

The ground run-up test was carried out on 30 April 2023 at PT. Nusantara Aircraft Maintenance, Hasanuddin International Airport, Makassar. At the time of testing, the engine was fully installed on-wing and configured according to the manufacturer's maintenance requirements, representing an operational aircraft environment rather than a test-cell configuration. This setup allowed the assessment of EEC performance under realistic installation conditions, including interactions with aircraft systems and integrated sensors.

The EGR test was performed in accordance with the Aircraft Maintenance Manual (AMM) Boeing 737-800 NG, Chapters 70-00-00 to 80-00-00, which specify standard post-maintenance procedures and acceptance criteria for engine performance verification. The test aimed to confirm that the replaced engine and its associated EEC system operated within prescribed operational limits prior to flight release.

During the test, the EEC governed and monitored critical engine parameters, including fan speed (N1), compressor speed (N2), exhaust gas temperature (EGT), fuel flow, oil pressure, oil temperature, and engine vibration. All measurements were obtained from the aircraft's built-in sensor system, ensuring consistency with operational avionics data used in routine maintenance and certification practices.

2.2 Electronic Engine Control (EEC) and Engine System Overview

The Electronic Engine Control (EEC) system serves as the primary digital control and monitoring unit governing the operation of the CFM56-7B turbofan engine. During engine operation, the EEC continuously receives inputs from multiple aircraft and engine-mounted sensors and processes this information in real time to regulate critical parameters, including fuel flow, fan speed (N1), compressor speed (N2), exhaust gas temperature (EGT), and lubrication-related variables. Through this closed-loop control architecture, the EEC ensures that engine performance remains within the operational limits specified by the manufacturer while maintaining stable and safe operating conditions [21].

Fuel flow regulation is achieved through coordinated interaction between the EEC and the hydromechanical unit (HMU), which meters fuel delivery to the combustion chamber based on commanded thrust and measured engine states. The fuel system incorporates high-pressure fuel pumps, fuel metering valves, and shutoff valves that operate under EEC supervision to ensure accurate fuel scheduling and safe operation throughout engine start, acceleration, and steady-state conditions [18][20]. In addition, a fuel flow transmitter positioned downstream of the fuel nozzle filter provides continuous feedback to the EEC, enabling precise monitoring of fuel consumption during the ground run-up test.

The lubrication system operates in parallel with the fuel control system to maintain adequate oil pressure and temperature across all power settings. Oil cooling is supported by oil–fuel heat exchangers and auxiliary cooling components, which contribute to thermal stability during high-power operation and transient conditions [19]. Measurements of oil pressure, oil temperature, and oil quantity are integrated into the EEC monitoring framework, allowing abnormal lubrication behavior to be detected during the test.

The EEC is also interfaced with aircraft systems, including cockpit controls, start levers, and safety interlocks, enabling coordinated engine start, power modulation, and shutdown sequences. Through these interfaces, the EEC manages protective functions such as overtemperature prevention, overspeed protection, and fault detection, which are essential for post-maintenance verification. The functional interaction between the EEC, fuel system, lubrication system, and aircraft interfaces during the Engine Ground Run-Up test is illustrated in Figure 1, which provides a system-level overview of the engine fuel and control architecture under on-aircraft conditions.

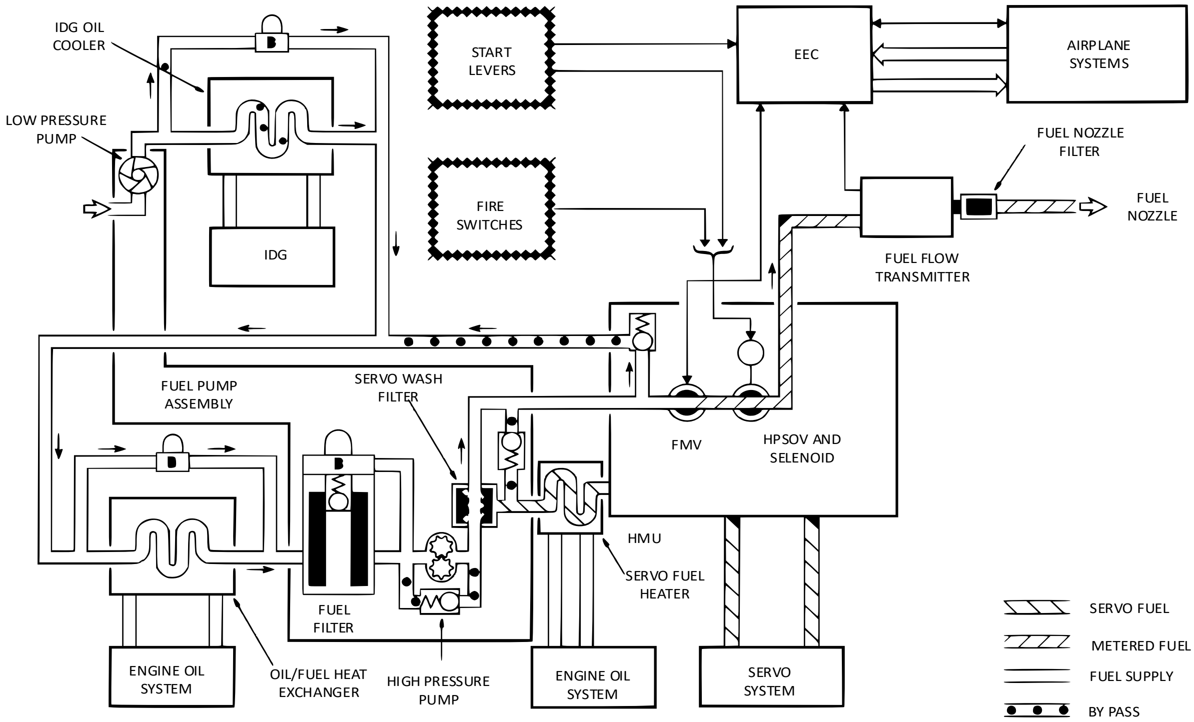

Figure 1. Functional overview of the engine fuel and electronic engine control system during engine ground run-up testing

Figure 1 illustrates the functional architecture of the engine fuel and Electronic Engine Control (EEC) system during the Engine Ground Run-Up test. Fuel is supplied from the aircraft fuel tanks and delivered through the fuel pump assembly, including filtration units, before being pressurized and regulated by the hydromechanical unit (HMU). The EEC governs fuel metering and shutoff functions by commanding fuel metering valves and high-pressure shutoff valves to ensure accurate fuel scheduling and safe engine operation. In parallel, the lubrication system—supported by oil–fuel heat exchangers and cooling components—maintains oil pressure and temperature within prescribed limits. Sensor feedback from fuel flow, rotational speeds (N1 and N2), exhaust gas temperature, oil parameters, and vibration is continuously processed by the EEC, enabling real-time monitoring, protection, and control of engine operation under on-aircraft ground run-up conditions.

2.3 Engine Ground Run-Up (EGR) Test Procedure

The Engine Ground Run-Up (EGR) test was conducted as a post-maintenance verification procedure to assess the operational performance of the Electronic Engine Control (EEC) system under on-aircraft conditions. The test followed the procedures specified in the Aircraft Maintenance Manual (AMM) Boeing 737-800 NG, Chapters 70-00-00 to 80-00-00, which define the required sequence, safety limits, and acceptance criteria for ground engine operation after maintenance activities.

The test sequence comprised three principal operating stages: engine start and idle stabilization, Maximum Power Assurance (MPA) at approximately 70% N1, and static take-off power. During engine start, the EEC controlled fuel scheduling and ignition to ensure a stable and gradual acceleration to idle speed. After idle stabilization, engine power was increased to the MPA setting to verify mid-range control stability and thermal behavior. The final stage involved a controlled increase to static take-off power to evaluate EEC performance at high thrust levels while maintaining all parameters within manufacturer-specified limits. The overall test sequence and verification checkpoints are illustrated in Figure 2. As illustrated in Figure 2, data acquisition and verification checkpoints were applied at each operating stage to capture both transient and steady-state EEC responses during the ground run-up sequence.

Throughout the EGR procedure, the EEC regulated engine operation by processing real-time sensor inputs and commanding actuator responses to maintain safe and stable transitions between power settings. Particular attention was given to transient behavior during acceleration, with the test acceleration time maintained within eight seconds to capture representative EEC response characteristics. Safety monitoring was continuously applied during all stages of the test, allowing the procedure to be aborted immediately in the event of abnormal indications.

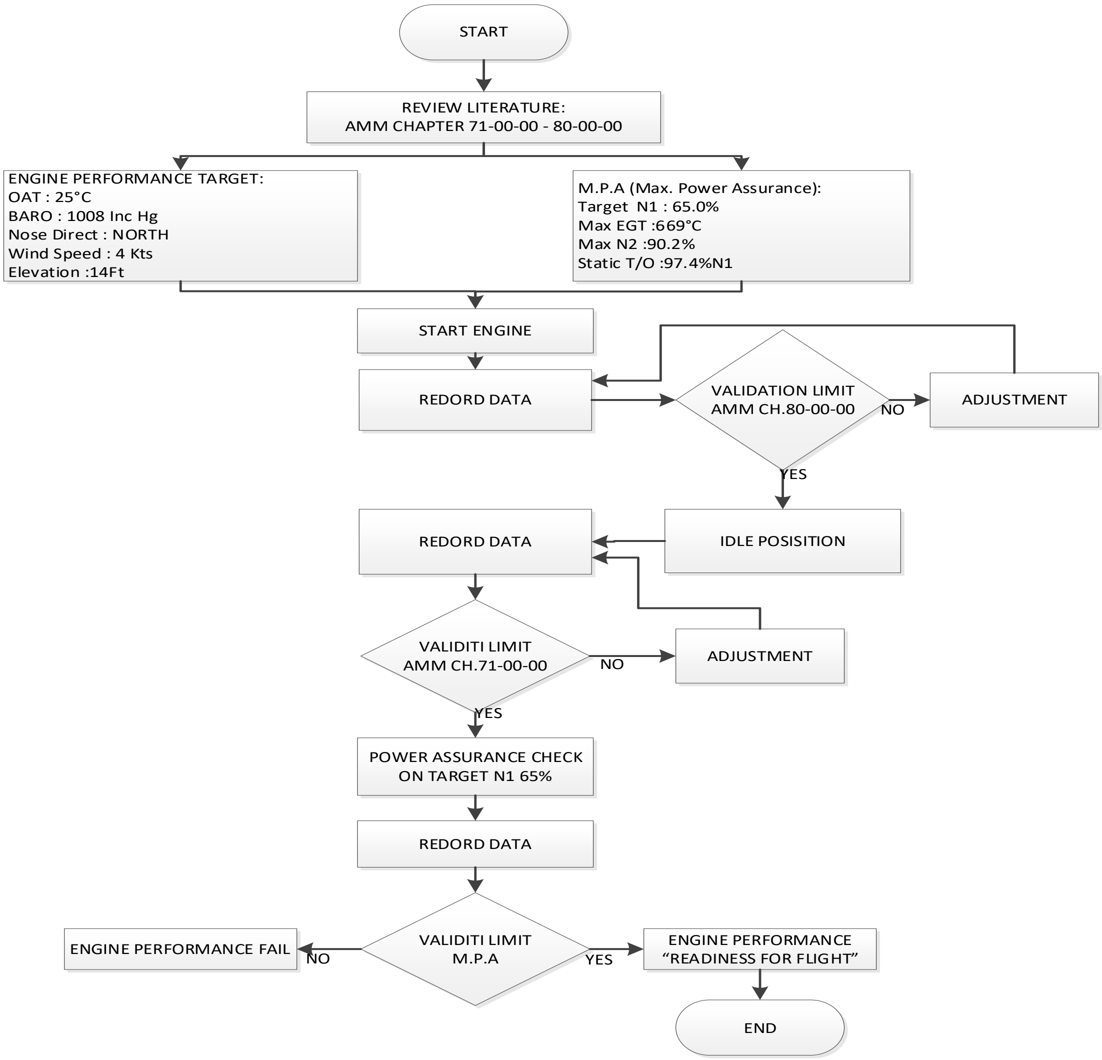

Figure 2. Schematic of the engine ground run-up (EGR) test sequence and EEC verification stages

The EGR procedure enabled comprehensive evaluation of EEC functionality without exposing the aircraft to the risks associated with immediate flight testing. By conducting the test under controlled ground conditions and in strict compliance with manufacturer procedures, the EGR method provided a reliable and repeatable framework for post-maintenance verification prior to flight release.

2.4 Data Acquisition and Measurement Parameters

Data acquisition during the Engine Ground Run-Up (EGR) test was performed using the aircraft's built-in sensor system, which supplies real-time measurements to the Electronic Engine Control (EEC) and cockpit indication systems. This approach ensured that all recorded data were representative of operational avionics signals routinely used for engine monitoring, maintenance verification, and flight release decisions.

The parameters monitored and recorded during the test included fan speed (N1), compressor speed (N2), exhaust gas temperature (EGT), fuel flow, oil pressure, oil temperature, oil quantity, and engine vibration. These parameters were selected because they are directly governed or supervised by the EEC and constitute the primary indicators of engine performance, control stability, and post-maintenance health status.

Data were collected during both transient and steady-state operating conditions across all EGR stages, namely idle stabilization, Maximum Power Assurance (MPA), and static take-off power. The engine acceleration time was maintained within eight seconds, allowing transient EEC responses to be captured while ensuring compliance with manufacturer safety limits. This enabled evaluation of EEC behavior during throttle changes as well as verification of parameter stability at each power setting.

To ensure measurement reliability, recorded sensor data were cross-checked against cockpit indicators and manual engine run-up log sheets in accordance with the procedures specified in the Aircraft Maintenance Manual (AMM). Fuel consumption was determined by comparing fuel quantity readings before and after the EGR test, with particular attention given to the center fuel tank, which supplied fuel during the run-up procedure. Environmental conditions—including ambient temperature, barometric pressure, wind direction, and wind speed—were also recorded to provide contextual information for subsequent data interpretation.

All acquired data were organized according to operating stage and compared against the corresponding manufacturer-specified limits defined in the AMM. This data handling approach ensured consistency between avionics sensor outputs, maintenance documentation, and acceptance criteria used for post-maintenance engine validation.

2.5 Reference Standards and Acceptance Criteria

The evaluation of engine performance and Electronic Engine Control (EEC) functionality during the Engine Ground Run-Up test was conducted by referencing the Aircraft Maintenance Manual (AMM) Boeing 737-800 NG, Chapters 70-00-00 to 80-00-00, which define the standard operating limits and acceptance criteria for post-maintenance engine verification. These standards specify the allowable ranges for key parameters, including N1, N2, exhaust gas temperature (EGT), fuel flow, oil pressure, oil temperature, and engine vibration, under idle, intermediate, and high-power conditions.

In addition to engine performance limits, system-level acceptance criteria were applied to verify the proper operation of supporting aircraft systems, such as the electrical power system, bleed air system, lubrication system, and EEC-related control functions, in accordance with manufacturer requirements [22]. Compliance with these reference standards provides the basis for determining whether the engine and its associated control systems are fit for return to service following maintenance or engine replacement [23].

The evaluation criteria applied in this study were derived from the Aircraft Maintenance Manual (AMM) Boeing 737-800 NG, Chapters 70-00-00 to 80-00-00, which define the allowable performance limits and system acceptance thresholds for post-maintenance Engine Ground Run-Up testing. The corresponding reference limits are summarized in Tables 1 and 2.

Table 1. Reference engine performance limits for CFM56-7B during engine ground run-up testing (AMM-based)

Parameter	Normal Idle Limit	Normal Take Off Limits
N1 (%)	20-22%	96–98%
N2 (%)	60-62%	99–100%
EGT (°C)	<500°C	<950°C
Fuel Flow (Kg/s)	$8.33\text{-}13.9 \times 10^{-5}$	$1.11\text{-}1.39 \times 10^{-3}$
Oil Pressure (Psi)	20-25	45-55
Oil Temp (°C)	110-120	110-120
Oil Quantity (%)	>12%	>12%
Vibration (Unit)	<1.5 unit (maximum)	<1.5 unit (maximum)

Note: The listed limits are derived from the Aircraft Maintenance Manual (AMM) Boeing 737-800 NG, Chapters 70-00-00 to 80-00-00, and are used as acceptance criteria for post-maintenance Engine Ground Run-Up testing [24].

Table 2. Reference system test acceptance criteria for CFM56-7B during Engine Ground Run-Up testing

Normal Engine Condition	System Test
395 - 405. Hzt	Gen. Frequency
110 - 120 Volt	Gen. Voltage
“OFF" (Depressurized)	E.D.P. Switch
“ON" (2850 - 3200 psi)	E.D.P. Switch
COWL ANTI - ICE	Cowl Anti - Ice
18-20 psi	Bleed Air Press. N1 Idle
26-36 psi	Bleed Air Press. N1 30-50%
34-50 psi	Bleed Air Press. N1 60-80%
42%-56% psi	Bleed Switchover. N1
0-6 psi	Bleed Switch Off
IDG	Idg Disconnect/Reconnect Test

Note: These system test limits are specified in the AMM Boeing 737-800 NG and are applied to verify proper operation of engine support systems during post-maintenance ground testing [24].

3. RESULTS AND DISCUSSION

3.1 Test Conditions and Fuel Consumption

The Engine Ground Run-Up (EGR) test was conducted under stable environmental conditions to ensure that the observed engine responses were representative of normal ground operation. As summarized in Table 3, the ambient temperature during testing was 25 °C, with a barometric pressure of 1008 hPa, wind speed of 4 knots, and a field elevation of 14 ft. These conditions are within the typical operational envelope specified for post-maintenance ground testing and did not impose abnormal thermal or aerodynamic loads on the engine.

Table 3. Environmental conditions during the Engine Ground Run-Up test

Parameters	Air Temperature (OAT)	Barometric Pressure	Wind Direction	Wind Speed	Elevation
Measurement results	25°C	1008 hPa	North, Nose Direct	4 Kts	14 ft

Fuel consumption during the EGR test was evaluated using a before–after fuel quantity comparison, as presented in Table 4. The recorded data indicate that fuel consumption occurred primarily from the center fuel tank, while the left-hand and right-hand tanks remained unchanged throughout the test. The total fuel quantity decreased from 9570 kg prior to testing to 8610 kg after completion of the run-up sequence, resulting in a net fuel consumption of 960 kg during the EGR procedure.

Table 4. Fuel quantity before and after Engine Ground Run-Up testing

Fuel Data	Before	After
LH. Tank (Kgs)	3850	3850
CTR. Tank (Kgs)	1870	910
RH Tank (Kgs)	3850	3850
Total (Kgs)	9570	8610

This fuel usage is consistent with the applied power settings, which included idle stabilization, Maximum Power Assurance (MPA), and static take-off power stages. The observed fuel consumption reflects appropriate fuel scheduling by the Electronic Engine Control (EEC) under controlled ground conditions and indicates stable fuel metering behavior throughout the test. No abnormal fuel flow fluctuations or indications of leakage were observed during or after the run-up sequence, supporting the validity of the recorded measurements for subsequent performance evaluation.

3.2 EEC Performance During Engine Start and System Verification

The performance of the Electronic Engine Control (EEC) during engine start and subsequent system verification was evaluated to ensure stable control behavior and proper integration with supporting aircraft systems following engine replacement. The engine start characteristics recorded during the Engine Ground Run-Up test are summarized in Table 5, which captures key parameters associated with ignition, spool acceleration, exhaust gas temperature, and fuel flow during the start sequence.

Table 5. Engine start characteristics during engine ground run-up testing

Measurement results	Starting Time (Second)
LH	Ignition (LH or RH)
25	Start Level Idle (N2%)
9.17×10^{-5}	Initial F/F (Kg/s)
56	Starter Cut Off (N2%)
492	Peak EGT (°C)
1.194×10^{-4}	Peak Fuel Flow (Kg/s)
60	Starting Time (Second)
19.30	Eng starts (Time/Minutes)
20.09	Eng stops (Time/Minutes)
39	Duration (Time/Minutes)
590	Fuel Used (Kgs)

The recorded start data indicate that the engine transitioned smoothly from ignition to stabilized idle without abnormal indications. Key parameters such as starter cut-off, peak EGT, and initial fuel flow remained within the allowable limits specified in the Aircraft Maintenance Manual, demonstrating that the EEC effectively managed fuel scheduling and ignition timing during transient start conditions. No abnormal EGT rise, excessive acceleration, or unstable idle behavior was observed, indicating proper coordination between the EEC, fuel control system, and starter mechanism.

In addition to engine start performance, system-level verification was conducted to assess the operation of supporting aircraft systems that interact with or are supervised by the EEC. The results of the system tests are presented in Table 6, covering the electrical power system, bleed air system, lubrication-related functions, and Integrated Drive Generator (IDG) operation. Measured values for generator frequency and voltage, bleed air pressure at various N1 settings, and engine-driven pump operation were all found to be within the reference ranges defined by the manufacturer. Supporting system verification results during Engine Ground Run-Up testing can be seen in Table 6.

Table 6. Supporting system verification results during engine ground run-up testing

Measurement Results	System Test
401	Gen. Frequency (395 - 405. Hzt)
115	Gen. Voltage (110 - 120 Volt)
OK	E.D.P. Switch 'Off" (Depressurized)
2990	E.D.P. Switch 'On" (2850 - 3200 Psi)
OK	Cowl Anti - Ice
20	Bleed Air Press. N1 Idle (18-20 Psi)
30	Bleed Air Press. N1 30-50% (26-36 Psi)
48	Bleed Air Press. N1 60-80% (34-50 Psi)
40	Bleed Switchover. N1 (42%-56% Psi)
3	Bleed Switch Off (0-6 Psi)
OK	Idg Disconnect/Reconnect Test

The combined results of the engine start evaluation and system verification confirm that the EEC maintained stable control and monitoring of engine operation during the initial and intermediate phases of the ground run-up test. Proper system responses and the absence of fault indications provide assurance that the engine and its associated avionics systems were correctly configured and functioned as intended prior to progression to higher power settings.

3.3 EEC-Controlled Engine Performance Across Power Settings

The performance of the Electronic Engine Control (EEC) was further evaluated by examining engine responses across successive power settings during the Engine Ground Run-Up test, namely idle, Maximum Power Assurance (MPA), and static take-off power. The measured engine parameters governed by the EEC are summarized in Table 7, while the corresponding MPA performance indicators are presented in Table 8.

Table 7. EEC-controlled engine performance parameters across power settings

Parameters	Idle (POS.1)	Idle (POS.2)	M.P.A (70% N1) (POS.1)	T/O Power (POS.1)
N1 (%)	20.5	21.0	65.0	97.4
EGT (°C)	466	493	585	855
N2 (%)	60.6	60.7	89.3	99.8
Fuel Flow (Kg/s)	8.61×10^{-5}	9.17×10^{-5}	4.11×10^{-4}	1.18×10^{-3}
Oil Pressure (Psi)	21	22	45	50
Oil Temp (°C)	119	115	96	115
Oil Quantity (%)	17	16	16	17
Vibration (Unit)	0.1	0.1	0.2	0.5

Table 8. Maximum Power Assurance (MPA) performance indicators

Target N1 (%)	Max EGT (°C)	Max N2 (%)	Static T/O (%N1)
65.0	669	90.2	97.4

As engine power increased from idle to higher thrust levels, the EEC maintained stable and proportional control of fan speed (N1), compressor speed (N2), exhaust gas temperature (EGT), and fuel flow. At idle conditions, N1 and N2 remained within the expected low-speed range, accompanied by moderate EGT values that indicate stable combustion. When engine power was increased to the MPA setting at approximately 70% N1, all monitored parameters exhibited smooth transitions without overshoot or abnormal fluctuations, demonstrating effective EEC modulation during mid-range operation.

At static take-off power, the EEC successfully regulated engine performance at high thrust levels. N1 and N2 approached their respective upper operational limits, while EGT remained below the manufacturer-defined maximum threshold, preserving an adequate thermal safety margin. Fuel flow increased proportionally with engine power, reflecting appropriate fuel scheduling by the EEC in response to increased thrust demand. Lubrication-related parameters, including oil pressure, oil temperature, and oil quantity, remained stable across all power settings, indicating proper integration between the EEC and the lubrication system. Engine vibration levels also remained well within acceptable limits, suggesting satisfactory mechanical balance and control stability following engine replacement.

Overall, the observed parameter trends confirm that the EEC provided consistent and reliable control of engine operation throughout the full range of ground test power settings. The absence of abnormal parameter excursions or instability during both transient and steady-state conditions indicates that the EEC effectively governed engine behavior under on-aircraft ground testing, supporting its role as a critical avionics system for post-maintenance verification.

3.4 Comparison with Previous Studies and Operational Implications

To place the present findings in context, the results of the on-aircraft Engine Ground Run-Up (EGR) test were compared with previously reported turbofan engine performance data obtained under test-cell–based conditions, particularly the work of Turgut et al. [12]. Test-cell studies such as these have been widely used to characterize baseline engine performance under controlled conditions; however, they do not fully account for installation effects and integrated aircraft system interactions that are present during on-aircraft operation.

The comparison, summarized in Table 9 and illustrated in Figures 3 and 4, shows that the overall performance trends observed during the EGR test are consistent with those reported in test-cell evaluations, confirming the validity of ground-based performance assessment [12]. At idle and Maximum Power Assurance (MPA) conditions, the EGR test exhibited slightly lower exhaust gas temperature (EGT) values than those reported in test-cell data, as shown in Figure 3, indicating efficient combustion and favorable thermal behavior under on-wing conditions. Similar reductions in idle and intermediate EGT have been reported in studies addressing engine performance under realistic operational environments [7][12].

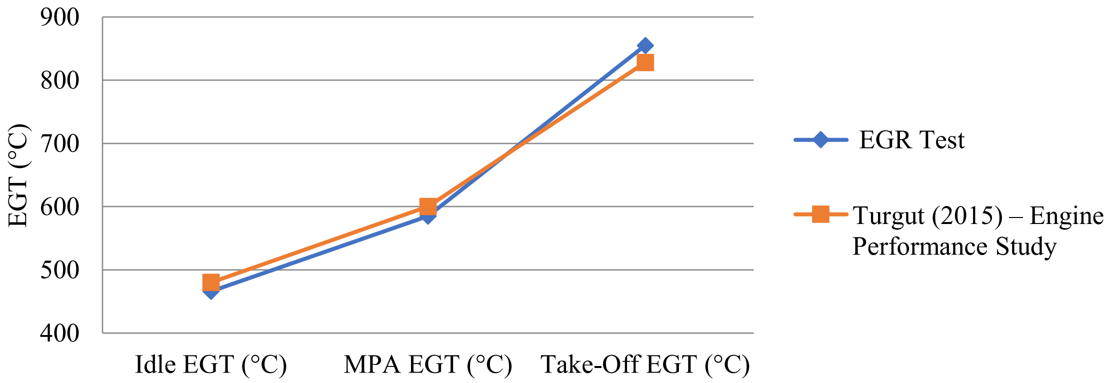

Figure 3. Comparison of exhaust gas temperature (EGT) between on-aircraft Engine Ground Run-Up testing and test-cell–based data

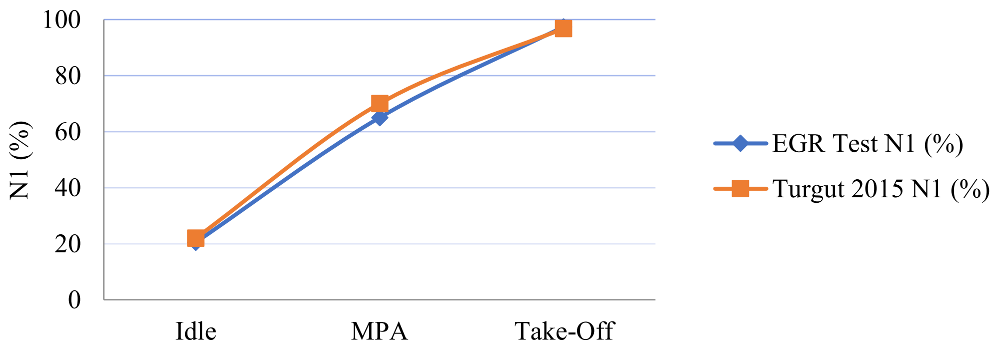

Figure 4. Comparison of fan speed (N1) between on-aircraft Engine Ground Run-Up testing and test-cell–based data

Table 9. Comparison of CFM56-7B engine performance parameters between on-aircraft Engine Ground Run-Up testing and test-cell–based studies

Measured Parameters	EGR Test	Turgut (2015) – Engine Performance Study	Major Differences
Test Method	Ground Run-Up on aircraft	Standard performance data (test-cell & operational)	Actual EGR testing conditions with the engine installed on-wing.
Idle N1 (%)	20.5	22	The lower idle EGT reflects higher thermal efficiency and indicates that the thermal section is in a healthy condition, with minimal heat stress and effective cooling performance at low rotational speeds.
Idle EGT (°C)	466–493	480–540	The lower EGT observed at engine idle indicates higher operating efficiency, as less thermal energy is required to maintain stable combustion
MPA N1 (%)	65.0	70-80	The MPA target established during the EGR test confirms that the engine can generate thrust at 65% N1 under on-wing conditions. In test-cell evaluations, this target is not specified because the engine has not yet been installed on-wing, and therefore thrust performance cannot be fully represented.
MPA EGT (°C)	585	600–680	The lower MPA EGT reflects efficient combustion and compressor–turbine performance, reducing the thermal load on the engine and supporting improved component durability under operational conditions.
Take-Off N1 (%)	97.4	96.8–97.5	Although the EGR was conducted at a lower idle setting (20.5% N1), the take-off power achieved was nearly equivalent to the test-cell results obtained at 22% N1, indicating that on-wing conditions and EEC control optimization may enhance thrust delivery despite lower initial spool speed.
Take-Off N2 (%)	99.8	99.1–99.6	The take-off N2 value reached 99.8%, closely matching real in-flight conditions (100%), indicating that the EGR test environment provides engine operating characteristics similar to those experienced during actual flight, particularly in terms of spool dynamics and airflow loading.
Take-Off EGT (°C)	855	828–873	The higher take-off EGT observed during the ground run is normal, as the absence of ram-air effect reduces cooling airflow through the engine, requiring increased combustion to achieve maximum thrust.
Fuel Flow TO (kg/s)	1.18	0.915–1.103	The higher fuel flow observed during the EGR test is attributed to the lack of ram-air effect, which lowers inlet air density and requires the EEC to increase fuel scheduling to achieve comparable N1/N2 performance to in-flight conditions, thereby maintaining stable combustion and thrust output.
Vibration	0.1–0.5	Not specified	The vibration levels observed during the EGR test indicate that the engine is in a healthy condition.
Oil Pressure (psi)	21–50	Not specified	The oil pressure observed during the EGR test indicates that the engine is in a healthy condition.

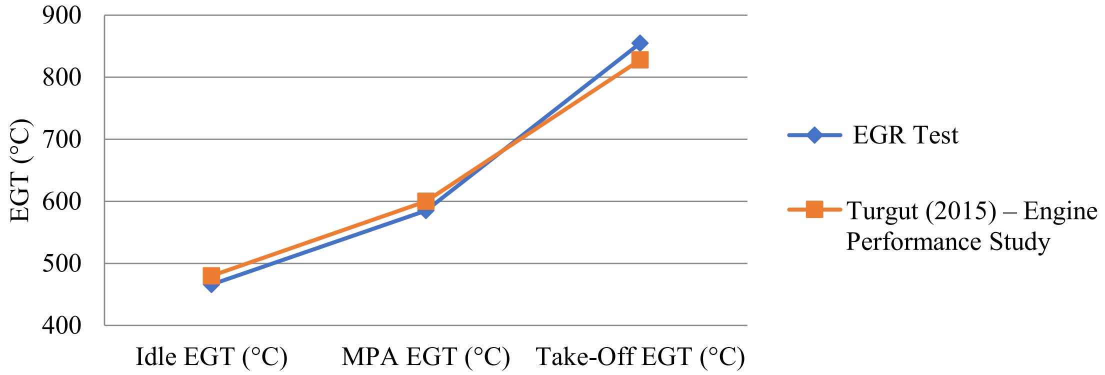

Figure 5. Comparison of exhaust gas temperature (EGT) between on-aircraft Engine Ground Run-Up testing and test-cell–based data

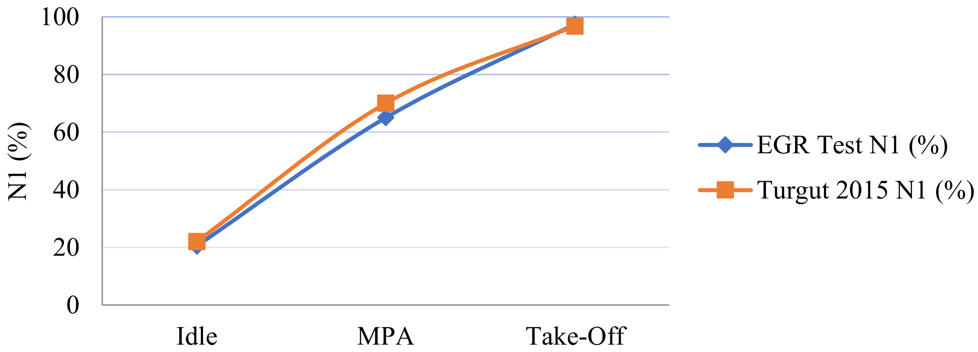

Figure 6. Comparison of fan speed (N1) between on-aircraft Engine Ground Run-Up testing and test-cell–based data

At static take-off power, the EGR test produced marginally higher EGT and fuel flow compared with test-cell values. This behavior is expected during ground operation due to the absence of the ram-air effect, which normally enhances cooling and inlet airflow during flight. Previous studies on turbofan engine ground testing and installation effects have also reported increased fuel scheduling and thermal loading under static conditions to achieve comparable thrust levels [12]. The present findings therefore align with established understanding of on-ground versus in-flight performance behavior.

A similar agreement was observed in the fan speed (N1) and high-pressure spool speed (N2) responses. As illustrated in Figures 3 and 4, the N1 and N2 trends across idle, MPA, and take-off power closely match those reported in test-cell and operational reference studies [12]. Minor deviations observed at the MPA stage are attributed to differences in inlet flow characteristics and airframe integration effects, which are inherently absent in off-wing test-cell configurations.

From an operational perspective, these results demonstrate that EGR testing provides a reliable intermediate validation step between maintenance completion and flight testing. By capturing EEC-controlled parameter behavior under actual on-aircraft installation conditions, the EGR approach bridges the gap between conventional test-cell analysis and real operational performance [6]. The ability of the Electronic Engine Control (EEC) to maintain stable regulation of speed, temperature, fuel flow, lubrication, and vibration parameters across all tested power settings confirms its effectiveness as a safety-critical avionics system for post-maintenance verification [5][18].

Overall, the comparison confirms that while test-cell evaluations remain essential for baseline engine characterization, on-aircraft EGR testing offers additional insight into integrated engine–aircraft–avionics behavior. This capability supports more informed maintenance decisions, enhances predictive maintenance practices, and reduces operational risk prior to flight release.

4. CONCLUSION

This study confirms that on-aircraft Engine Ground Run-Up (EGR) testing is an effective, reliable, and operationally representative method for validating the performance of the Electronic Engine Control (EEC) system of the CFM56-7B engine following post-maintenance installation. All EEC-controlled parameters—including fan speed (N1), compressor speed (N2), exhaust gas temperature (EGT), fuel flow, lubrication parameters, and vibration—remained within the acceptance limits specified in the Aircraft Maintenance Manual, demonstrating stable EEC regulation during both transient acceleration and steady-state operation. Comparison with test-cell–based studies shows consistent performance trends, while also highlighting expected differences attributable to on-wing installation effects and the absence of ram-air cooling during ground operation. By providing empirical evidence of EEC behavior under actual aircraft integration conditions, this work bridges the gap between conventional test-cell evaluations and real operational validation. The findings support the role of EGR testing as a safe, cost-effective alternative to immediate flight testing and reinforce its value for post-maintenance verification, predictive maintenance, and the assurance of engine reliability and flight safety in commercial aviation.

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