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Analysis of the Effect of Compressor Washing on the Inter Turbine Temperature (ITT) Margin of the PW127 Engine

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Abstract. Aircraft engine performance and reliability are critical factors in ensuring flight safety and operational efficiency. One of the key parameters used to assess the condition of the Pratt & Whitney PW127M turboprop engine is the Inter-Turbine Temperature (ITT) Margin, which represents the available temperature margin relative to the maximum allowable limit. A reduction in ITT Margin generally indicates a decrease in thermal efficiency, often caused by compressor contamination. This study aims to analyze the effect of compressor washing on the ITT Margin of PW127M engines installed on ATR 72-600 aircraft. The research was conducted on ten PW127M engine units operated by PT Wings Abadi Airlines over a four-month observation period, consisting of two months before and two months after compressor washing. Data were collected from the EMRO system, engine logbooks, and Engine Condition Trend Monitoring (ECTM) reports. The analysis employed descriptive statistical methods and a paired sample t-test to evaluate the significance of ITT Margin changes. The results show that all engines experienced an increase in ITT Margin after compressor washing, with an average improvement of 4.9 °C. Statistical testing produced a t-value of 7.10 and a p-value of 0.0000568 (<0.05), indicating a statistically significant difference. These findings confirm that compressor washing is effective in improving engine thermal performance and should be considered an integral part of condition-based maintenance strategies.

Keywords: *Compressor Washing, ITT Margin, PW127M Engine, ATR 72-600, Paired Sample t-Test, ECTM.*

A. INTRODUCTION

The aviation industry demands a high level of engine reliability and performance to ensure flight safety and operational efficiency. For regional aviation operations, turboprop engines remain the preferred propulsion system because of their superior fuel efficiency and capability to operate economically on short- and medium-haul routes. One of the most widely operated regional aircraft is the ATR 72-600, which is powered by the Pratt & Whitney Canada PW127M turboprop engine, specifically designed to provide reliable performance under various operating conditions.

One of the key indicators used to evaluate the thermal condition of a turboprop engine is the Inter-Turbine Temperature (ITT) Margin. The ITT Margin is defined as the difference between the manufacturer's maximum allowable inter-turbine temperature limit and the actual ITT measured during engine operation, particularly during engine start. A decreasing ITT Margin indicates engine performance degradation, which may increase the risk of overtemperature conditions and adversely affect engine durability and reliability. Consequently, ITT Margin has become one of the primary parameters monitored through the Engine Condition Trend Monitoring (ECTM) program to assess engine health.

One of the primary causes of engine performance deterioration is compressor fouling, which occurs due to the accumulation of contaminants such as dust, salt particles, and oil residues on compressor blades. These deposits reduce compressor aerodynamic efficiency, resulting in higher gas temperatures required to produce the same engine power output. To mitigate this problem, a maintenance procedure known as compressor washing is routinely performed to remove contaminants from the compressor section, restore airflow efficiency, and improve the engine's thermal performance.

Although compressor washing has become a standard maintenance practice in the aviation industry, quantitative evaluations of its effectiveness in improving ITT Margin—particularly for PW127M engines operating under actual airline conditions—remain limited. Maintenance decisions are frequently based on operational experience rather than comprehensive statistical analysis. Therefore, an objective, data-driven investigation is required to quantify the effect of compressor washing on engine thermal performance.

This study aims to analyze the effect of compressor washing on the ITT Margin of Pratt & Whitney Canada PW127M engines installed on ATR 72-600 aircraft operated by PT Wings Abadi Airlines. The analysis compares ITT Margin values before and after compressor washing using the paired-sample t-test. The findings are expected to provide scientific evidence supporting the implementation of condition-based maintenance (CBM) strategies and contribute to improving aircraft engine reliability and operational performance.

B. METHOD

1. Research Design

This study employed a quantitative research method with a comparative approach. The analysis focused on comparing Inter-Turbine Temperature (ITT) Margin values before and after the implementation of compressor washing. The required data were collected from the Engine Monitoring and Reliability Office (EMRO) system, Engine Condition Trend Monitoring (ECTM) reports, engine logbooks, and available maintenance records.

The research sample consisted of ten PW127M engine units that met the predetermined completeness and consistency criteria. The analytical procedure included data collection, data verification, descriptive statistical analysis, normality testing, and hypothesis testing using the paired-sample t-test. This approach was selected to determine whether the changes in ITT Margin following compressor washing were statistically significant or merely caused by random variation.

2. Research Object and Location

The object of this study was the Pratt & Whitney Canada PW127M turboprop engine installed on ATR 72-600 aircraft operated by PT Wings Abadi Airlines. The research utilized operational and maintenance data collected directly from the airline's maintenance system, thereby representing actual operational conditions.

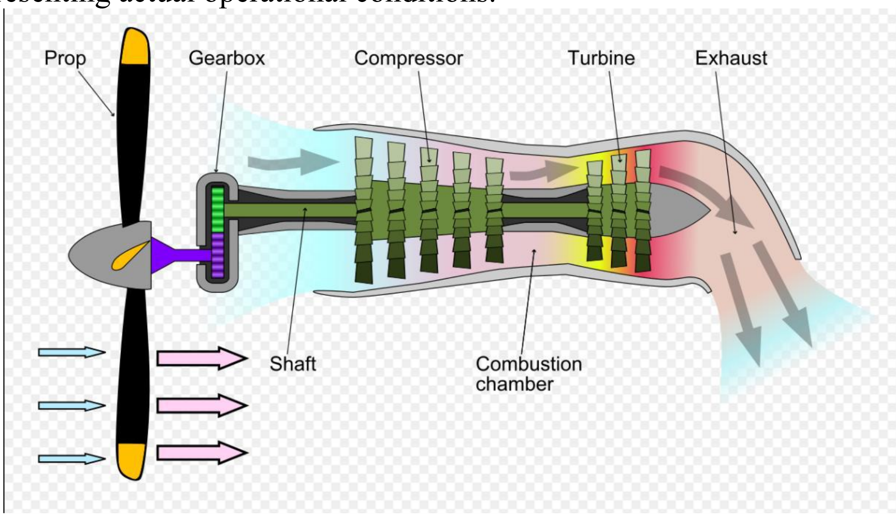

Figure 1. Engine Turboprop

Figure 2. Illustration of the Pratt & Whitney Canada PW127 Turboprop Engine

3. Data and Data Source

The study employed secondary data obtained from several reliable sources within the aircraft engine monitoring and maintenance system, including the Engine Monitoring and Reliability Office (EMRO) database, Engine Condition Trend Monitoring (ECTM) reports, engine logbooks, and engine maintenance records.

The EMRO system served as the primary source of historical engine performance data, including operational parameters and long-term performance trends. ECTM reports were used to evaluate changes in engine condition based on periodically recorded performance parameters, providing comprehensive information regarding engine health before and after maintenance activities. Meanwhile, engine logbooks and maintenance records were utilized to verify the timing of compressor wash procedures and ensure the accuracy of maintenance-related information for each engine.

The analysis focused specifically on Inter-Turbine Temperature (ITT) Margin recorded during engine start, both before and after compressor washing. The pre-maintenance data represented engine conditions prior to compressor cleaning, whereas the post-maintenance data were collected shortly after compressor washing to maintain operational consistency. The comparison of these datasets was intended to identify changes in ITT Margin that reflected improvements or deterioration in engine thermal efficiency. Consequently, this analysis provides a comprehensive evaluation of the effect of compressor washing on aircraft engine performance, particularly in terms of thermal margin and overall engine efficiency.

4. Population and Sample

The population of this study comprised all PW127M engines installed on ATR 72-600 aircraft operated by PT Wings Abadi Airlines**.** The research sample consisted of ten PW127M engines that met the selection criteria, namely complete ITT Margin data recorded both before and after compressor washing. A purposive sampling technique was employed to ensure that only engines with complete, consistent, and reliable operational data were included in the analysis.

5. Research Variables

The study involved one independent variable and one dependent variable. The independent variable was compressor washing, defined as the engine compressor cleaning process intended to remove contaminants such as dirt, dust, salt deposits, and oil residues accumulated on compressor blades. Compressor washing is a preventive maintenance procedure designed to restore compressor airflow efficiency and improve overall engine performance. In this study, compressor washing was treated as the intervention expected to influence engine performance. The dependent variable was the Inter-Turbine Temperature (ITT) Margin, expressed in degrees Celsius (°C). ITT Margin is defined as the difference between the maximum allowable inter-turbine temperature specified by the manufacturer and the actual ITT measured during engine start. This parameter is widely recognized as an indicator of engine thermal health and operational efficiency.

A higher ITT Margin indicates better engine condition because the engine operates further below its maximum allowable temperature limit. Conversely, a reduction in ITT Margin indicates deterioration in engine performance and thermal efficiency. Therefore, this study examined changes in ITT Margin before and after compressor washing to evaluate the effectiveness of the maintenance procedure in improving engine performance and reliability.

6. Data Analysis Method

The data analysis was conducted through several systematic stages to ensure accurate, valid, and scientifically reliable results. The first stage involved descriptive statistical analysis, which was performed to summarize the characteristics of the ITT Margin data before and after compressor washing. Descriptive statistics included the calculation of the mean, minimum value, maximum value, and standard deviation, providing an overview of data distribution and variation. The second stage consisted of a normality test performed on the differences between pre- and post-maintenance ITT Margin values. The purpose of this test was to verify whether the data satisfied the normality assumption required for parametric statistical analysis. Normality was evaluated using either the Shapiro–Wilk or Kolmogorov–Smirnov test. The data were considered normally distributed when the p-value exceeded the significance level ($\alpha = 0.05$).

Once the normality assumption had been satisfied, a paired-sample t-test was conducted to determine whether the differences in ITT Margin before and after compressor washing were statistically significant. This statistical test was selected because the observations consisted of paired measurements obtained from the same engine under two different conditions.

The statistical hypotheses were defined as follows:

H_0**:** There is no statistically significant difference in ITT Margin before and after compressor washing.

H_1: There is a statistically significant difference in ITT Margin before and after compressor washing.

The decision criterion was based on the p-value. The null hypothesis (H_0) was rejected when $p < 0.05$; otherwise, it was not rejected. In addition, the statistical decision was supported by comparing the calculated t-value with the critical t-value. All statistical analyses were performed using IBM SPSS Statistics and Microsoft Excel, which facilitated accurate calculations and enabled the presentation of results in tables and graphical formats. This comprehensive analytical procedure was expected to provide valid and reliable conclusions regarding the influence of compressor washing on ITT Margin and its contribution to improving aircraft engine maintenance effectiveness and performance.

7. Research Flow

The research procedure was organized systematically to ensure that each stage was conducted sequentially and produced comprehensive, scientifically reliable results. The first stage involved data collection, in which ITT Margin values recorded during engine start were gathered for periods before and after compressor washing. The data were obtained from the EMRO system, ECTM reports, engine logbooks, and maintenance records, ensuring that they accurately represented actual engine operating conditions.

The second stage consisted of data screening and validation. The collected data were carefully reviewed to verify their completeness, consistency, and accuracy. Incomplete, irrelevant, or anomalous records that could potentially affect the analysis were excluded. Furthermore, engine performance data were cross-checked with compressor washing schedules to ensure that the compared observations accurately represented pre- and post-maintenance conditions within an appropriate time interval.

The third stage involved descriptive statistical analysis, including the calculation of the mean, minimum value, maximum value, and standard deviation for both pre- and post-compressor washing conditions. This analysis provided an initial understanding of performance trends and data variability.

The fourth stage comprised hypothesis testing using the paired-sample t-test. Prior to hypothesis testing, a normality test was performed on the differences in ITT Margin values to verify compliance with the assumptions required for parametric analysis. The paired-sample t-test was then conducted at a 5% significance level ($\alpha = 0.05$) to determine whether compressor washing produced statistically significant improvements in ITT Margin.

The final stage involved the interpretation of the statistical results and the formulation of conclusions. The findings were interpreted based on established theories of engine performance and thermal efficiency to determine whether compressor washing significantly improved ITT Margin. Finally, conclusions and practical recommendations were developed to support future aircraft engine maintenance strategies.

C. RESULT AND DISCUSSION

1. Descriptive Analysis of ITT Margin

A descriptive statistical analysis was conducted to evaluate changes in the Inter-Turbine Temperature (ITT) Margin before and after compressor washing on PW127M engines. The analysis included data collected from ten engine units that met the predetermined selection criteria.

Table 1. Descriptive Statistic of ITT Margin

Parameter	Before Compressor Wash (°C)	After Compressor Wash (°C)
Number of Samples (n)	10	10
Minimum Value	685	690
Maximum Value	690	695
Mean	687,1	692,0
Standard Deviation	2,02	2,21

As presented in Table 1, the average ITT Margin increased following compressor washing. The mean ITT Margin improved from 687.1°C before maintenance to 692.0°C afterward, representing an average increase of 4.9°C. This improvement indicates a noticeable recovery in the engine's thermal performance after the compressor cleaning procedure.

2. Analysis of ITT Margin Differences

To further examine the effect of compressor washing, the differences in ITT Margin before and after maintenance were analyzed for each engine.

Table 2. Comparison of ITT Margin before and after Compressor Washing

No	Engine	ITT Before (°C)	ITT After (°C)	Difference (°C)
1	Engine 1	690	695	5
2	Engine 2	685	690	5
3	Engine 3	688	693	5
4	Engine 4	687	692	5
5	Engine 5	686	690	4
6	Engine 6	689	694	5
7	Engine 7	685	690	5
8	Engine 8	688	692	4
9	Engine 9	687	692	5
10	Engine 10	688	693	5

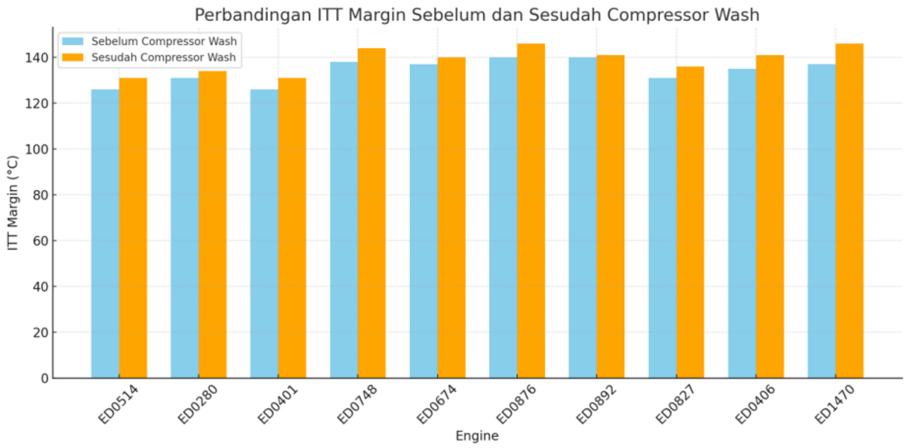

Figure 3. Comparison of ITT Margin Before and After Compressor Washing

Table 2 demonstrates that all engine units exhibited an increase in ITT Margin following compressor washing. The observed improvements ranged from 4°C to 5°C, indicating that compressor washing consistently produced positive effects on engine thermal performance across all sampled engines.

To determine whether the observed improvement in ITT Margin was statistically significant, a paired-sample t-test was performed.

Table 3. Result of the Paired Sample t-Test

Parameter	Value
Mean Difference ($\bar{y}$)	4,9 °C
Standard Deviation (s)	2,18
Number of Samples (n)	10
T-value	7,10
Degrees of Freedom (df)	9
p-value	0,0000568
Significance Level (α)	0,05

The statistical analysis produced a calculated t-value of 7.10 with a p-value of 0.0000568, which is substantially lower than the significance level of 0.05. Therefore, the null hypothesis (H_0) was rejected, while the alternative hypothesis (H_1) was accepted, indicating a statistically significant difference in ITT Margin before and after compressor washing.

The findings demonstrate that compressor washing has a significant positive effect on improving the Inter-Turbine Temperature (ITT) Margin of the Pratt & Whitney Canada PW127M engine. The average improvement of 4.9°C indicates a measurable recovery in engine thermal performance following the compressor cleaning process.

These findings are consistent with the established theory that compressor fouling reduces compressor aerodynamic efficiency by restricting airflow through the compressor stages. The accumulation of contaminants such as dust, salt particles, and oil residues increases compressor losses, requiring higher turbine gas temperatures to maintain the same power output. Consequently, compressor washing restores airflow efficiency, decreases thermal loading, and improves overall engine performance.

Another important observation is the consistent improvement across all ten engine units included in this study. Every engine experienced an increase in ITT Margin after compressor washing, demonstrating that the maintenance procedure is not only effective on individual engines but also provides reliable and repeatable results under actual airline operating conditions. Such consistency is particularly important for commercial aircraft maintenance, where standardized maintenance outcomes contribute directly to fleet reliability and operational efficiency.

The statistical results further reinforce these observations. The paired-sample t-test yielded a p-value of 0.0000568, which is significantly lower than the established significance threshold of 0.05. This result confirms that the observed improvement in ITT Margin is not attributable to random variation, but rather represents the direct effect of compressor washing. Therefore, the statistical evidence strongly supports the effectiveness of the compressor cleaning procedure in restoring engine thermal efficiency.

These findings are in agreement with previous studies reported by Seddigh et al. (2002), Stalder (2015), Meher-Homji and Bromley (2004), and Archibong-Eso et al. (2023), which concluded that compressor washing effectively mitigates compressor fouling, enhances compressor efficiency, improves gas turbine thermal performance, and contributes to longer engine component life.

From an operational perspective, the improvement in ITT Margin provides several important benefits for airline operators. A larger ITT Margin indicates that the engine operates further below its maximum allowable temperature limit, thereby reducing the likelihood of overtemperature events and minimizing thermal stress on turbine components. This contributes to increased component durability, reduced maintenance costs, improved dispatch reliability, and enhanced flight safety.

Furthermore, the findings support the implementation of condition-based maintenance (CBM) strategies in which compressor washing is scheduled according to engine performance indicators rather than fixed maintenance intervals. By integrating ITT Margin monitoring through the Engine Condition Trend Monitoring (ECTM) system, maintenance personnel can optimize compressor washing intervals based on actual engine condition, thereby improving maintenance efficiency while reducing unnecessary maintenance actions.

Overall, this study provides quantitative evidence that compressor washing is an effective maintenance practice for restoring engine thermal performance and maintaining the operational reliability of PW127M engines installed on ATR 72-600 aircraft.

D. CONCLUSION

Based on the results and discussion presented in this study, it can be concluded that compressor washing has a statistically significant positive effect on improving the Inter-

Turbine Temperature (ITT) Margin of the Pratt & Whitney Canada PW127M engine installed on ATR 72-600 aircraft.

All engine units included in this study exhibited an increase in ITT Margin following compressor washing, with an average improvement of 4.9°C. This finding indicates that compressor washing effectively restores engine thermal performance by improving compressor efficiency and reducing thermal loading during engine operation.

The results of the paired-sample t-test yielded a p-value of 0.0000568, which is significantly lower than the predetermined significance level of 0.05. Therefore, the improvement in ITT Margin observed after compressor washing is statistically significant rather than the result of random variation. These findings confirm that compressor washing is an effective maintenance procedure for restoring engine thermal efficiency and increasing the available temperature margin below the manufacturer's maximum allowable limit.

The consistent improvement observed across all engine samples further demonstrates that compressor washing is a reliable maintenance practice suitable for implementation within a condition-based maintenance (CBM) program. Incorporating this procedure into routine maintenance activities can enhance engine reliability, reduce the risk of overtemperature events, extend component service life, and improve both flight safety and operational efficiency.

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