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Analysis of Engine Gas Path Cleaning Effectiveness on Engines in Aircraft

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***Abstract* - An analysis of the effectiveness of engine gas path cleaning (EGPC) was conducted on a General Electric engine used by the aircraft. The main objectives of the study were to evaluate the impact of EGPC on engine performance, specifically on the Exhaust Gas Temperature (EGT) and EGT Margin parameters, and to determine the most efficient maintenance interval to maintain optimal performance. Data were collected from four engines spanning a one-year period before and after the maintenance. The methods used included direct observation, interviews with technical personnel, and analysis of operational data obtained from the My GE Aerospace Fleet Monitor portal. The results showed an increase in EGT Margin of 7.4 to 11.2°C and a decrease in actual EGT between 5.5 and 35.4°C in the first 50 flights after EGPC was performed. However, the benefits of this treatment only lasted for a range of 299 to 483 flight cycles, with an average effective period of approximately 372 cycles, before performance returned to its original condition. Based on these results, it is recommended to change the EGPC interval from 500 to 350 flight cycles to maintain engine efficiency and prevent excessive EGT increases. Further research is recommended to evaluate the long-term impact of increasing the EGPC frequency on corrosion risk, fuel consumption, and overall engine maintenance costs.**

Keywords: engine gas path cleaning, EGT, EGT Margin, flight cycle.

I. INTRODUCTION

The aviation industry is a rapidly growing transportation sector and plays a crucial role in global connectivity. As air mobility increases, the need for aircraft safety, efficiency, and operational reliability becomes increasingly crucial. Aircraft engines, as vital components of the aviation system, require regular maintenance designed not only to maintain optimal performance but also to extend engine life and minimize operational costs. One of the key parameters in monitoring engine condition is Exhaust Gas Temperature (EGT), which indicates combustion efficiency and the performance of the engine's thermal system. An uncontrolled increase in EGT can indicate a decline in engine performance and potentially cause further damage.

Engine gas path cleaning is a form of maintenance performed to clean the engine compressor section of deposits or dirt that accumulate while the engine is running. Cleaning this engine section is expected to have a positive effect on the engine (Abubakar, 2016). By carrying out engine gas path cleaning maintenance routinely and on a schedule, aircraft engine performance can be maintained at optimal condition. This maintenance allows the combustion system and airflow within the engine to remain clean of dirt or deposits that can interfere with thermal efficiency. Thus, the engine is able to produce thrust in accordance with operational standards without experiencing excessive increases in exhaust gas temperatures. This condition is very important to ensure smooth airline operations, reduce the risk of delays due to engine damage, and minimize fuel consumption and long-term maintenance costs.

Despite the widespread adoption of EGPC, questions remain regarding its long-term effectiveness and optimal maintenance intervals, particularly for the engines used on the Aircraft fleet. These engines play a critical role in airline operations, and performance degradation can significantly impact fuel efficiency and maintenance costs. This study aims to evaluate the impact of EGPC on engine performance based on EGT and EGT Margin parameters, and determine the most efficient maintenance intervals based on real-world operational data. The results of this study are expected to contribute to more effective and data-driven maintenance decision-making in the commercial aircraft engine maintenance sector.

II. MATERIAL AND METHOD

2.1 Gas Turbine System

The Aircraft is a long-range, wide-body, twin-turbofan civil passenger. This aircraft was introduced on June 12, 1994 and began serving customers on June 7, 1995. The General

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Electric is one of the most successful high-bypass ratio turbofan engines in this Aircraft.

A gas turbine is a prime mover that uses gas as a working fluid. In a gas turbine, kinetic energy is converted into mechanical energy in the form of rotation that drives the turbine wheel, thus producing power. The rotating part of the turbine is called the rotor, and the stationary part of the turbine is called the stator or turbine housing. The rotor turns the power shaft that drives the load (electric generator, pump, compressor, or others) (Salim, 2018). A gas turbine consists of three main components: the compressor, the combustion chamber, and the turbine. This system can function as a gas generator or generate shaft power. The main characteristics of a gas turbine are compact, lightweight, and capable of producing high power and are vibration-free. The energy produced by the gas turbine is then transferred to the hardware using a suitable working fluid. Sometimes air is circulated through the engine (Gusnita, 2017).

A turbofan engine is a gas turbine engine whose first compressor is larger than the gas turbine engine itself. This first compressor is the fan. Air passing through this fan enters the compressor, is then compressed by the engine, and then exits through the exhaust side. However, air passing through the outer diameter of the engine does not enter the engine core, but rather exits directly and produces thrust. Air that does not enter the engine core is called bypass, while the ratio between the air entering the engine core and that passing through the outer diameter of the engine is called the ratio, so the mass flow rate of bypass air to the mass flow rate of air entering the core is called the bypass ratio (El-sayed, 2016).

Exhaust gas temperature (EGT) is a measurement of the temperature of the air leaving the turbine engine. A high EGT can indicate decreased engine performance. An engine experiencing performance problems can result in inefficient operation and impair engine flow. In addition to monitoring performance, exhaust gas temperature is also used to monitor engine health. An engine with a high EGT can cause various problems. These problems will disrupt airline operations and increase unnecessary expenses.

In general, the EGT Margin is the estimated difference between the projected EGT at full liftoff above sea level and the EGT Redline. However, in reality, the EGT Margin is not simply a subtraction of the actual EGT from the EGT Redline; it involves a recalculation performed by the manufacturer, the calculation method of which is not disclosed. Therefore, the reduced margin value sometimes differs from the actual value.

2.2 Engine Gas Path Cleaning

Engine gas path cleaning, or washing the engine flow path, is one of the maintenance and care performed on aircraft turbofan engines. Compressor washing is also a way to repair compressors that have accumulated unwanted objects (Diwa, 2017). The purpose of this maintenance is to extend the useful life of the engine, prevent overheating, and maintain optimal engine performance. This engine gas path cleaning activity is in accordance with the Aircraft Maintenance Manual (AMM) and is reinforced by the established Maintenance Program (MP). On the aircraft, engine gas path cleaning is performed every 500 flight cycles. One flight cycle is calculated as one takeoff and one landing. Failure to perform engine gas path cleaning has many disadvantages. The main impact is an increase in exhaust gas temperature (EGT) in the engine. With an increase in EGT, many subsequent effects will arise.

The engine gas path cleaning process involves attaching two nozzles from the Juniper Compressor Wash RIG to the low-pressure compressor. Afterward, the engine is run dry, running at low rpm for two minutes. The water used is preheated to 70°C. After heating, it is sprayed into the engine's compressor at a certain pressure. This process is repeated up to three times.

Dirt that accumulates in the engine can also reduce aerodynamic efficiency, making the engine less efficient. This suboptimal engine efficiency will undoubtedly impact unsatisfactory engine performance and increase exhaust gas temperatures. Dirt containing certain substances can also cause engine corrosion and further damage.

2.3 Data Collection

The data analyzed was data from four General Electric engines on a aircraft over a one-year period (February 11, 2024-February 11, 2025). Several methods were used to collect the data and obtain the results, including direct observation of the engine gas path cleaning process in the hangar, interviews with company engineers, and data collection through the fleet monitor page. The data collected is as follows, where number 10 indicates one flight before the engine gas path cleaning and number 11 indicates one flight after the engine gas path cleaning.

Table 1: Engine data number 1

No.	Flight Date Time	EGT Hot Day Margin-TAKEOFF	EGT-TAKEOFF
1.	2024-06-02 18:23:49	29,15067505	928,9
2.	2024-06-03 05:45:19	23,79452424	895,9

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3.	2024-06-04 01:20:59	31,27137108	963,3
4.	2024-06-04 13:56:57	24,33946134	894,2
5.	2024-06-05 08:10:35	27,457118	948,8
6.	2024-06-05 20:01:00	28,26529053	882,5
7.	2024-06-06 09:30:09	29,00000051	943,2
8.	2024-06-06 21:32:57	19,21367445	905,5
9.	2024-06-07 09:49:11	28,36011008	940,9
10.	2024-06-07 21:38:58	26,11926708	890,3
11.	2024-06-11 05:01:29	38,61559362	830,2
12.	2024-06-11 07:55:12	36,27401253	834,2
13.	2024-06-11 11:44:38	36,77893314	865,2
14.	2024-06-11 23:49:54	40,38166867	930,9
15.	2024-06-12 11:53:09	41,13029173	867,9
16.	2024-06-12 23:58:58	38,58755466	936,9
17.	2024-06-14 07:55:26	34,72806323	854,3
18.	2024-06-14 10:58:38	38,29373766	823,2
19.	2024-06-15 07:42:16	32,99724209	861,2
20.	2024-06-15 10:47:14	36,7091598	824

Table 2: Engine data number 2

No.	Flight Date Time	EGT Hot Day Margin-TAKEOFF	EGT-TAKEOFF
1.	2024-07-22 10:01:28	33,27035975	969,7
2.	2024-07-22 21:08:30	28,10386459	1003,7
3.	2024-07-23 09:20:12	26,55576756	1009,6
4.	2024-07-23 21:12:09	31,16022942	1001,1
5.	2024-07-24 09:43:52	33,04265727	933,1
6.	2024-07-24 20:52:09	25,35143547	1059,6
7.	2024-07-25 09:40:00	32,93379367	934,2
8.	2024-07-25 21:09:44	34,06749226	993,7
9.	2024-07-26 09:16:58	26,07502136	855,7
10.	2024-07-26 12:04:50	28,20298669	830,2
11.	2024-07-27 05:11:11	35,92341854	954,5
12.	2024-07-27 16:57:22	39,15391	999,4
13.	2024-07-28 05:26:09	40,42258	974,7
14.	2024-07-28 16:48:08	41,66631	961,1
15.	2024-07-29 05:16:47	33,55684	976,1
16.	2024-07-29 16:47:06	36,10694	992,2
17.	2024-07-30 07:52:38	32,20843	1020,4
18.	2024-07-30 19:11:02	39,30128	981,4
19.	2024-07-31 08:59:12	38,30642	928,7
20.	2024-07-31 20:14:41	29,22445	1054

Table 3: Engine data number 3

No.	Flight Date Time	EGT Hot Day Margin-TAKEOFF	EGT-TAKEOFF
1.	2024-08-13 09:17:07	28,09402332	984,9
2.	2024-08-13 21:49:32	30,03114292	1014,7
3.	2024-08-14 10:14:02	19,08421357	959,6
4.	2024-08-14 22:34:56	24,90769489	1016,1
5.	2024-08-16 04:52:20	10,12002918	870,8
6.	2024-08-16 08:03:52	23,26187851	846,7
7.	2024-08-17 08:59:48	15,49432969	950
8.	2024-08-17 20:08:51	19,99764305	1065,9
9.	2024-08-18 08:19:53	19,50577977	889,8
10.	2024-08-18 11:18:19	17,87274521	864,4
11.	2024-08-19 00:32:00	24,34145953	863,7
12.	2024-08-19 04:03:26	26,86293358	881,3
13.	2024-08-19 10:05:42	33,27584135	954,5
14.	2024-08-19 22:38:56	27,78236525	1051,1
15.	2024-08-20 11:46:55	35,56294739	951,2
16.	2024-08-20 23:41:14	41,81342407	993,4
17.	2024-08-21 11:50:05	32,77519309	933,7
18.	2024-08-21 23:55:34	39,00383286	957,7
19.	2024-08-22 11:58:15	34,23939498	950
20.	2024-08-23 00:01:19	36,06052605	944,8

Table 4: Engine data number 4

No.	Flight Date Time	EGT Hot Day Margin-TAKEOFF	EGT-TAKEOFF
1.	2024-08-06 10:22:22	13,34595153	895,8
2.	2024-08-06 13:19:08	16,40529671	843,1
3.	2024-08-07 00:25:53	14,18542243	871,9
4.	2024-08-07 04:32:26	19,55534207	863,7
5.	2024-08-07 08:43:41	18,88958954	968,1
6.	2024-08-07 20:27:00	22,99900604	1067,9
7.	2024-08-08 08:46:24	21,13481525	968,1
8.	2024-08-08 19:54:13	21,07222353	1027,7
9.	2024-08-09 09:15:24	15,17747797	873
10.	2024-08-09 12:49:50	21,04800597	846
11.	2024-08-10 09:05:52	29,39169058	935,5
12.	2024-08-10 20:23:28	24,86403117	1056,8
13.	2024-08-11 08:44:14	22,14310483	865,6
14.	2024-08-11 11:39:04	22,80469117	857,5
15.	2024-08-12 00:26:41	21,23789865	858,7
16.	2024-08-12 04:15:46	27,73577147	835,2
17.	2024-08-12 08:52:37	26,39418196	940,3

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18.	2024-08-12 20:06:55	25,17116421	1056,9
19.	2024-08-13 09:17:07	31,58981278	978,7
20.	2024-08-13 21:49:32	34,38044193	1007,1

III. RESULT AND DISCUSSION

3.1 Analysis of the engine number 1

After performing engine gas path cleaning, there was an improvement in EGT Margin. The EGT Margin improvement was calculated by subtracting the average of the fifty flights before the engine gas path cleaning from the average of the fifty flights after the engine gas path cleaning.

Average EGTM 50 cycles after EGPC – average EGTM 50 cycles before EGPC:

= 37,3956 – 26,2337

= 11,1619

The EGT Margin graph analysis used is one year of flight data from February 11, 2024 to February 11, 2025 and engine gas path cleaning was carried out on June 11, 2024.

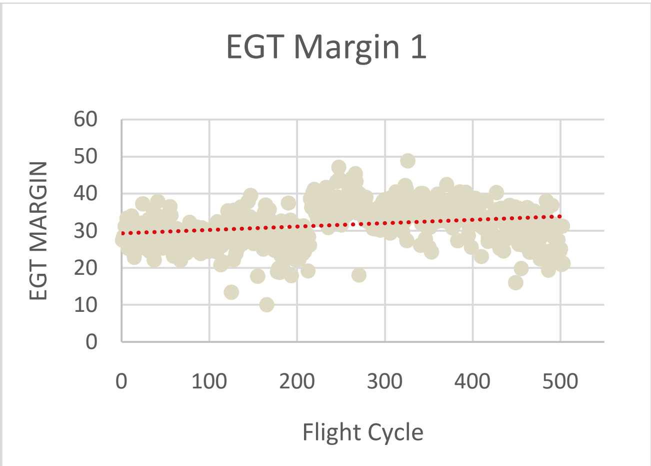

Figure 1: EGT Margin for Engine number 1

The calculation of actual EGT improvement is done by subtracting the average of fifty flights before engine gas path cleaning from the average of fifty flights after engine gas path cleaning.

Average 50 cycle before EGPC – average 50 cycle after EGPC:

= 928,165 – 893,54

= 34,616

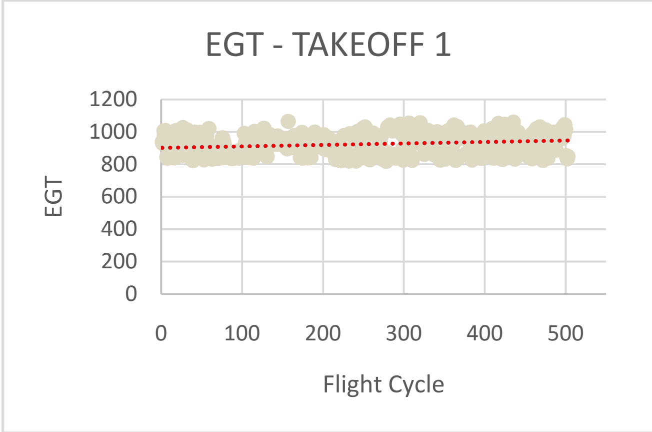

Figure 2: EGT Takeoff for Engine number 1

The EGT Margin graph in Graph 1 shows a decrease due to operational factors and contaminant buildup in the engine. After engine gas path cleaning, the EGT Margin increased by 11.2°C. This increase demonstrates the effectiveness of the cleaning in improving engine performance for up to 50 subsequent flights. However, this effectiveness only lasted for 483 flight cycles before the EGT Margin returned to its initial condition. On the other hand, the actual EGT graph in Graph 2 shows an odd upward trend that contradicts the EGT Margin, so further research is needed to identify the external factors causing this anomaly.

3.2 Analysis of the engine number 2

After engine gas path cleaning, there was an improvement in EGT Margin calculated from the average difference of 50 flights before and after cleaning.

Average 50 cycle before EGPC – average 50 cycle after EGPC:

= 36,6940 – 29,3054

= 7,3886

The EGT Margin graph used is one year of flight data from February 11, 2024 to February 11, 2025 and the EGPC was conducted on July 27, 2024.

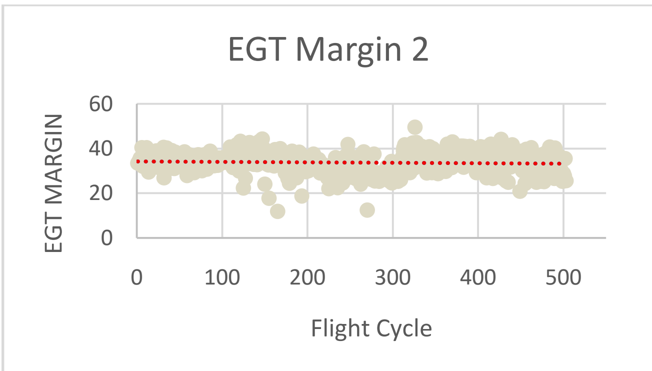

Figure 3: EGT Margin for Engine number 2

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The calculation of the actual EGT improvement is done by subtracting the average of fifty flights before engine gas path cleaning from the average of fifty flights after engine gas path cleaning.

Average 50 cycle before EGPC – average 50 cycle after EGPC:

= 957,578 – 922,174

= 35,404

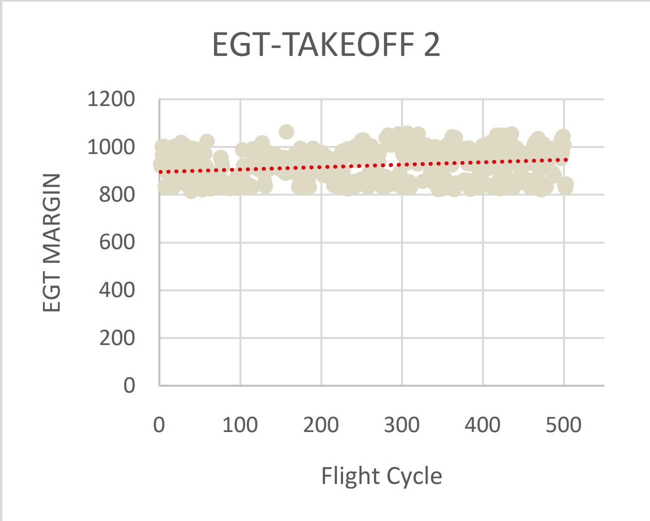

Figure 4: EGT Takeoff for Engine number 2

The decrease in EGT and EGT Margin values occurs due to the accumulation of contaminants and continuous engine use. After engine gas path cleaning, there was an increase in EGT Margin of 7.4°C, indicating an improvement in engine performance. However, this positive effect of cleaning only lasted for 387 flight cycles before the EGT Margin decreased back to its initial condition. However, after the cleaning process, the EGT value showed better stability, although it continued to increase slowly due to the natural degradation of engine components over time.

3.3 Analysis of the engine number 3

After performing engine gas path cleaning, there was an improvement in EGT Margin. The EGT Margin improvement was calculated by subtracting the average of the fifty flights before the engine gas path cleaning from the average of the fifty flights after the engine gas path cleaning.

Average 50 cycle before EGPC – average 50 cycle after EGPC:

= 31,5196 – 22,0749

= 9,4447

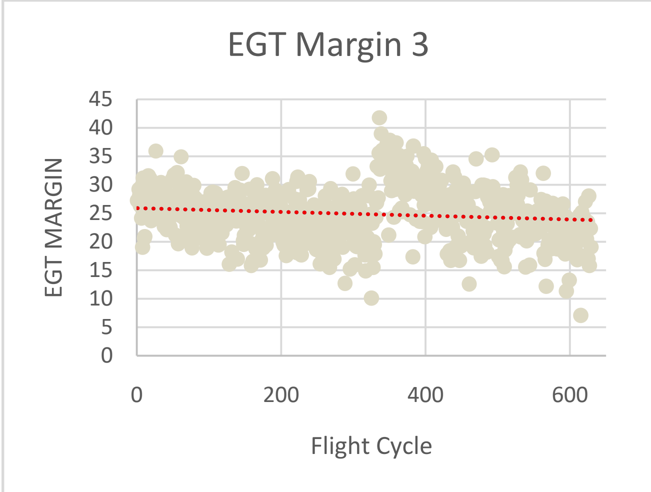

Figure 5: EGT Margin for Engine number 3

The calculation of the actual EGT improvement is done by subtracting the average of fifty flights before engine gas path cleaning from the average of fifty flights after engine gas path cleaning.

Average 50 cycle before EGPC – average 50 cycle after EGPC:

= 956,288 – 943,49

= 12,798

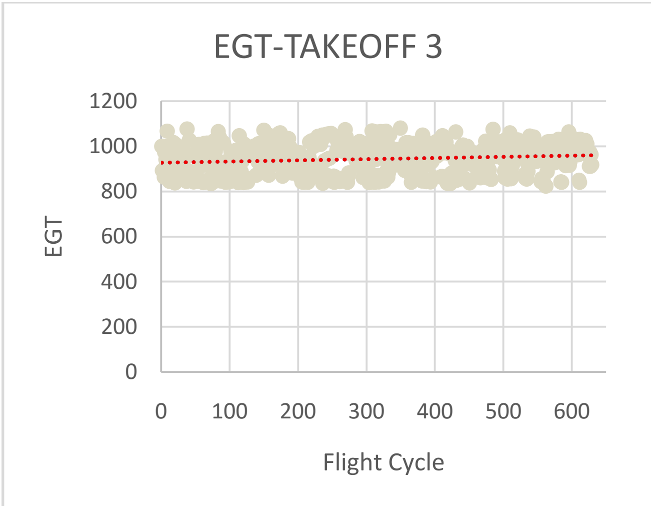

Figure 6: EGT Takeoff for Engine number 3

The decline in EGT and EGT Margin values occurred due to continuous engine use and the accumulation of contaminants in the gas path. After engine gas path cleaning, the EGT Margin increased by 9.5°C and the EGT value became more stable, without returning to the maximum value as before cleaning. This increase indicates an improvement in engine performance after cleaning. However, over time, natural degradation in the engine causes the EGT and EGT Margin values to decline again. The effectiveness of this

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cleaning was recorded to only last up to 299 flight cycles before performance conditions returned to a downward trend.

3.4 Analysis of the engine number 4

After engine gas path cleaning, there was an improvement in EGT Margin calculated from the average difference of 50 flights before and after cleaning.

Average 50 cycle before EGPC – average 50 cycle after EGPC:

= 27,8369-18,4289

= 9,408

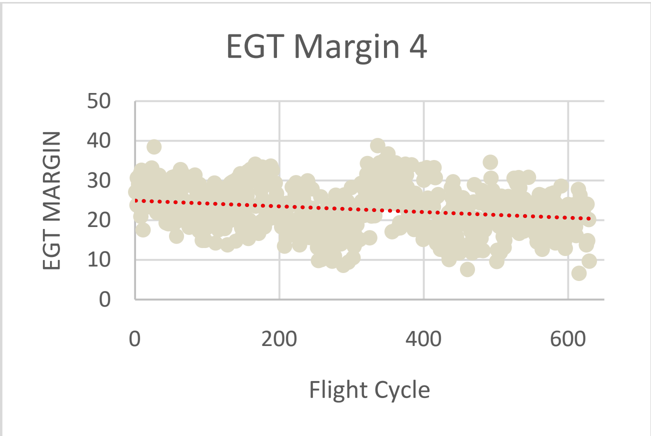

Figure 7: EGT Margin for Engine number 4

The calculation of actual EGT improvement is done by subtracting the average of fifty flights before engine gas path cleaning from the average of fifty flights after engine gas path cleaning.

Average 50 cycle before EGPC – average 50 cycle after EGPC:

= 953,038 – 947,508

= 5,53

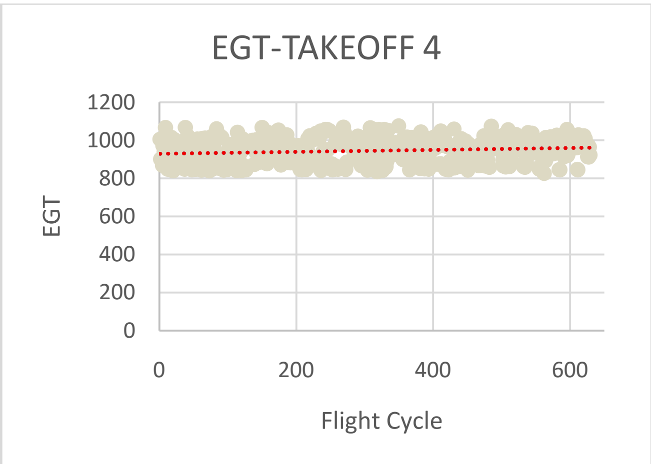

Figure 8: EGT Takeoff for Engine number 4

IV. CONCLUSION

From the data collection, analysis, and research conducted above, the following conclusions can be drawn:

1. Contaminants entering the engine are one of the factors causing an increase in exhaust gas temperature. This results in increased engine workload.
2. In the fifty flights following engine gas path cleaning, there was a significant increase in EGT Margin, enabling the engine to perform better.
3. Engine gas path cleaning effectively maintained negative EGT Margin and prevented EGT from reaching redline.
4. Using a sample of four GE90-115B engines out of fourteen active engines owned by the Company, the average EGT Margin decreased to the pre-engine gas path cleaning point after 372 flight cycles.
5. In addition to contaminants, numerous factors contribute to increased EGT and decreased EGT Margin values, including outside air temperature, air density, air pressure, air quality, air humidity, and many other factors. These factors require further research and cannot be discussed in this internship report.

SUGGESTION

Based on the conclusions obtained, the author can provide the following recommendations to companies:

1. Reduce the flight cycle for engine gas path cleaning from 500 to 350.
2. Further analyze the impact of this reduced flight cycle, such as the impact of engine corrosion on engines with more frequent engine gas path cleaning.
3. Further analyze the effect of engine gas path cleaning on fuel consumption reductions, maintenance costs, and its impact on airline operations.

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