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Commercial Gas Turbine Performance Analysis for Aviation Industries

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Abstract: The existing turbofan seems to fit perfectly with the current airline's demand, however, the performance of the engines can still be improved in a few aspects such as speed, fuel consumption, and component efficiency. Hence, the purpose of this study is to conduct performance analysis for available commercial gas turbine engines. The main objective of this study is to develop an engine model based on the available commercial gas turbines which then conduct a performance analysis on the engines. Another objective is to perform a comparison between the engine that had been analyzed. The study was simulated using GasTurb software. Two engines from commercial aircraft are determined first to ensure it is compatible to make a comparison for both engines. The engine then being analyzed by using GasTurb and the result and data then export into excel for further discussion. Both engine result from the performance analysis was then compared to determined which one is better. As a result, the highest thrust that GP7270 can produce is 372.157 kN while Trent 970-84 is 358.914 kN with the most altitude the thrust of Trent 970-84 is higher. The highest TSFC value for GP7270 13.044 g/(kN*s) while Trent 970-84 is 23.789 g/(kN*s). Fuel flow for both engines also significantly different with the highest fuel flow for GP7270 is 4.733 kg/s while Trent 970-84 is 8.538 kg/s. The propulsive efficiency also shows that Trent 970-84 have a higher value compare to GP7270 with a value of 0.771 and 0.578 respectively. Therefore, we could conclude that GP7270 is better compare to Trent 970-84 in terms of fuel efficiency even though Trent 970-84 could produce higher thrust and propulsive efficiency.

Keywords: Thrust, TSFC, Fuel Flow, Propulsive Efficiency

1. Introduction

Aviation signifies all the activities related to flying or operating the aircraft[1]. Technology evolution in the aviation industry speeds up exponentially because, over the last few years, the demand for aircraft operation is increasing especially in the commercial sector[2]. Due to the increased demand for aircraft operations, its technology also seems to evolve according to the interest of the aviation

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industry and to be exact, from the airlines themselves [3]. The interest of airlines in this context means that the operations of the aircraft must be fuel savings and low cost of operations. The operation from the existing aircraft seems to have some weakness where some of the aircraft operations will consume a lot of fuel and the performance of the aircraft are not efficient enough for certain operations [4]. In this case, an analysis needs to be done to create and develop a better performance for the aircraft.

Since most of the engine performance data is limited, there will be a problem where engineers could not determine what factors are affecting the performance of the engine[5]. Therefore, a simulation needs to be done to study and improve the engine performance. In this case, a performance analysis is the best way to be executed because when it comes to performance, it is mostly influenced by the changes of the parameters. Parameters could be divided into two, known as performance parameters and operation parameters. Therefore, in conducting a performance analysis for an engine, these parameters need to be emphasized. As we also know, a gas turbine is complex and it takes quite some time to determine its performance data if we are not using simulation in this research. By using a simulation for engine performance analysis, we could easily change the parameters according to our preference and it will consume less time compare to we change the parameters using manual calculations. This research at least could help new aircraft engineers to get an idea on which gas turbine engine will be the best for a commercial aircraft. In addition, researchers who are related to the aviation field will also benefit from this study as they can implement this performance analysis method in their research and become a reference for their research. Finally, this research will help to ease the learning process for aviation students where they can have a better understanding of engine performance based on data from GasTurb software and give them an idea of how certain factors might affect the engine performance.

2. Methodology

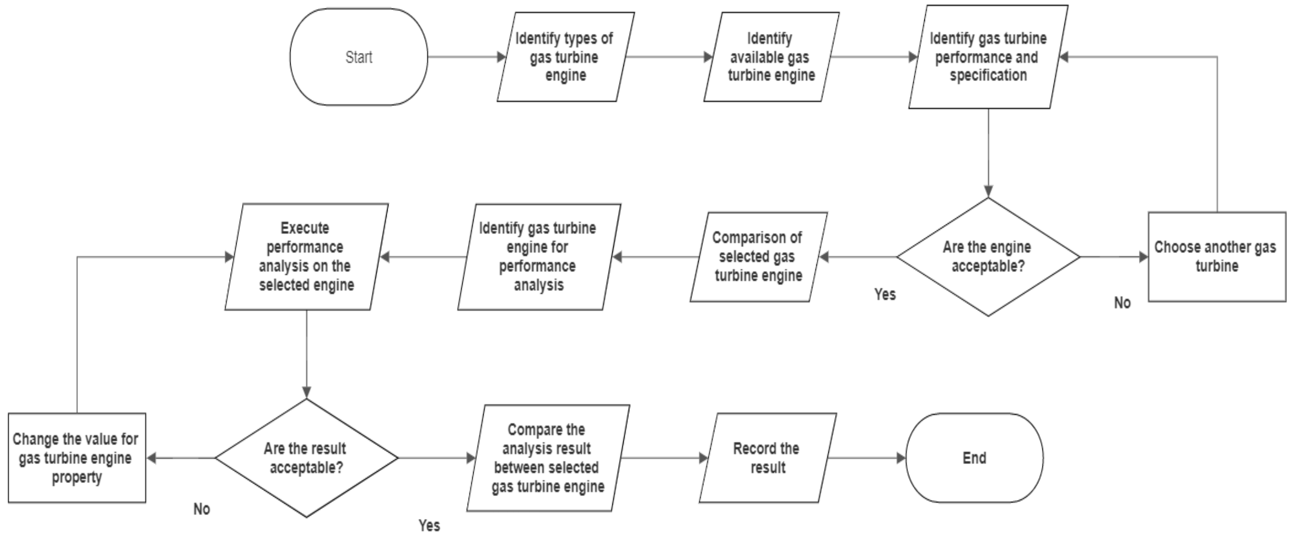
2.1 Turbofan engines

The performance analysis was conducted on two turbofan engines that are used in commercial applications. However, a few turbofan engines were identified first to select a better engine for the performance analysis. Table 1 shows the specification of the turbofan engine that had been selected to identify two engines that suitable for the performance analysis. GP7270 and Trent 970-84 engines had been chosen for the performance analysis because of their performance specifications.

Table 1: Engine specification

Engine	Type	Length (m)	Max thrust (kN)	Overall pressure ratio	Air mass flow (kg/s)
GP7270	Two spool high bypass turbofan engine	4.92	363	43.9:1	900
Trent 970-84	Three shafts high bypass turbofan engine	5.48	334.3	37:1	1204
GE9X	Dual rotor, axial flow, high bypass turbofan	5.69	490	60:1	-
Trent XWB-97	Three shaft high bypass turbofan engine	431	431	50:1	1436
Trent 1000-R	Three shaft high bypass ratio turbofan engine	4.738	360.4	50:1	1090
General Electric CF6	Dual rotor, axial flow high bypass ratio turbofan engine	4.27	310	34.8:1	-

2.2 Methodology flowchart



The study had been conducted by following the steps shows in the flowchart. As discussed in section 2.1, the engine had been identified first before conducting the performance analysis. Since there is no problem with the two selected engines, the performance analysis was then executed by using GasTurb software. The result of the performance analysis was then analyzed in a form of a graph and table. If the result is unacceptable, the value for the gas turbine engine property needs to be changed to obtain a new result. The performance analysis focused on a few parameters such as net thrust, thrust specific fuel consumption, fuel flow, and propulsive efficiency. Data obtained from the performance analysis will then be compared for both engines to determine which one is better for the commercial application. The result then being record in excel to help to analyze the data better.

3. Results and Discussion

3.1 GP7270 analysis

Table 2: Data export from excel (GP7270)

Altitude	Net thrust (kN)	TSFC [g/kN*s)]
0	379.474	12.473
1000	349.829	12.302
2000	319.888	12.001
3000	290.642	12.144
4000	262.617	12.119
5000	234.494	12.200
6000	208.348	12.303
7000	184.321	12.419
8000	162.363	12.546
9000	142.390	12.686
10000	124.304	12.839
11000	108.002	13.002
12000	92.241	13.018
13000	78.779	13.034

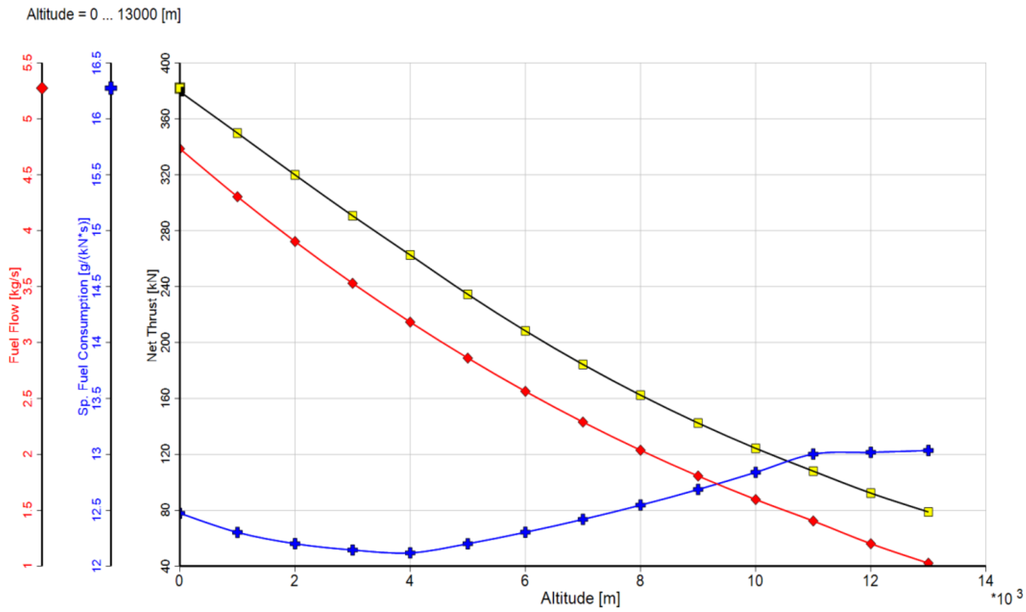


Figure 1: Net thrust, TSFC & fuel flow vs Altitude graph

Table 2 is the data obtained from the performance analysis for GP7270 which then interpret in a form of a graph as shown in Figure 1. The net thrust is the highest at altitude 0 m with a value of 379.474 kN and lowest at altitude 13000 m with a value of 78.779 kN. We could say that the engine produces the highest thrust in the early climbing process. As for TSFC, the highest TSFC value is at altitude 13000 m with a value of 13.034 g/(kN*s) and the lowest at altitude 4000 m with a value of 12.119 g/(kN*s). For fuel flow, the highest value is 4.8 kg/s at the lowest altitude and the lowest value is 1 kg/s at the highest altitude.

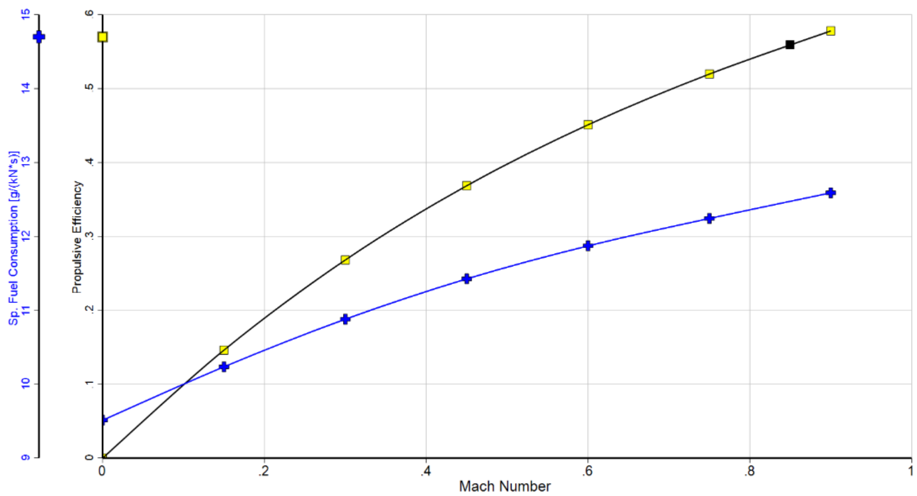


Figure 2: Propulsive efficiency & TSFC vs Mach number graph

Figure 2 is the graph for propulsive efficiency and TSFC against Mach number. As we can see in the graph, at Mach 0.85 TSFC is the highest where its value is equivalent to 12.473 g/(kN*s). In the case of propulsive efficiency, as the Mach number increase, the propulsive efficiency is increasing as well. The graph shows that at Mach 0.85, propulsive efficiency is the highest with a value of 0.58.

3.2 Trent 970-84 analysis

Table 3: Data export from excel (Trent 970-84)

Altitude	Net thrust (kN)	TSFC [g/kN*s)]
0	358.914	23.789
1000	368.748	21.182
2000	351.680	20.259
3000	328.277	19.737
4000	302.612	19.410
5000	276.459	19.201
6000	250.801	19.066
7000	225.936	18.998
8000	202.222	18.982
9000	179.874	19.010
10000	159.035	19.078
11000	139.770	19.178
12000	119.371	19.183
13000	101.950	19.190

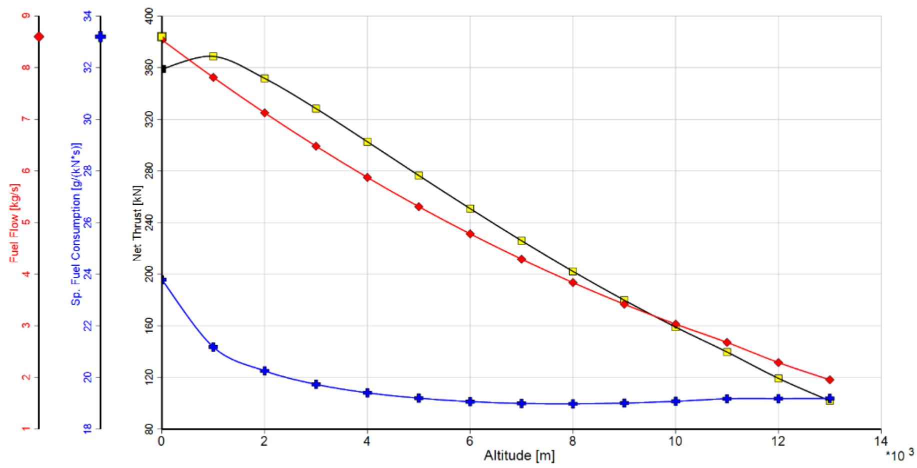


Figure 3: Net thrust, TSFC & fuel flow vs Altitude graph

Table 3 is the data that being export into excel to ease the discussion process. Figure 3 is the combined graph for net thrust, TSFC, and fuel flow against altitude for Trent 970-84. The net thrust is the highest at altitude 1000 m with a value of 368.748 kN and lowest at altitude 13000 m with a value of 101.950 kN. In the ideal condition, the thrust should be higher at the lowest altitude, but in this case, the highest thrust produce is at an altitude of 1000 m. As for TSFC, the highest TSFC value is at altitude 13000 m with a value of 19.190 g/(kN*s) and the lowest at altitude 8000 m with a value of 18.982 g/(kN*s). The weakness for the engine is because the combustion efficiency deteriorates when the altitude exceeds 9000 m which requires more fuel to produce the same energy at a lower altitude, thus make the TSFC value increase. The next parameter available in the graph is the fuel flow, the highest value is 8.5 kg/s while the lowest is 2 kg/s. Theoretically, for the combustion process in the burner to occur efficiently, the ratio of fuel and air must be equivalent.

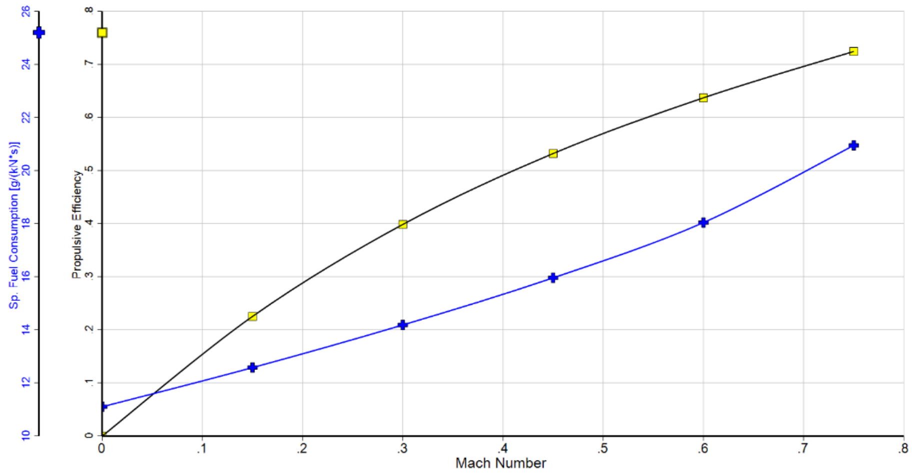


Figure 4: Propulsive efficiency & TSFC vs Mach number graph

Figure 4 shows the graph for propulsive efficiency and TSFC against Mach number for Trent 970-84. The trend of TSFC and propulsive efficiency almost the same with an increase of Mach number, the value of TSFC and propulsive efficiency also increase. Based on observation from the graph, at Mach 0.78, TSFC is the highest where its value is equivalent to 23.789 g/(kN*s). For propulsive efficiency, the value is the highest at Mach 0.75 with a value of 0.72. The propulsive efficiency is good since the ideal value for propulsive efficiency is 1 where the value will never exceed 1 in the real application.

3.3 Comparison between GP7270 and Trent 970-84

3.3.1 Net thrust comparison

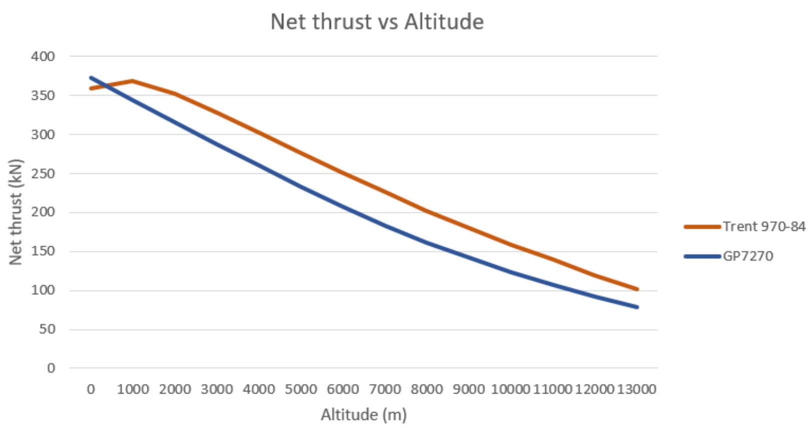


Figure 5: Net thrust vs altitude graph comparison

Based on Figure 5, we could say that net thrust for GP7270 is slightly higher than Trent 970-84 at altitude 0. However, Trent 970.84 produces a higher thrust as the altitude exceeds 1000 m. The highest value of thrust that GP7270 can produce is 372.157 kN while Trent 970-84 can produce 368.748 kN. On the other hand, both engines produce the lowest thrust at the highest altitude for this analysis which is at 13000 m. With GP7270 produce 78.508 kN and Trent 970-84 produce 101.95 kN, this shows that Trent 970-84 produce higher thrust than GP7270.

3.3.2 TSFC comparison

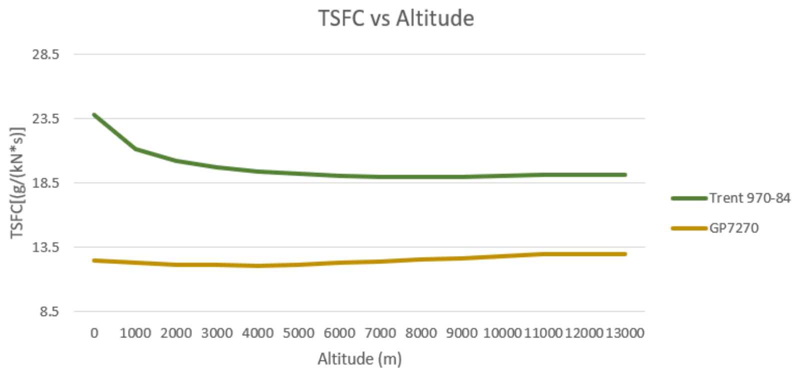


Figure 6: TSFC vs altitude graph comparison

As for comparison for both engines, the TSFC value for Trent 970-84 is higher at all altitudes. Despite this fact, GP7270 is better since a lower TSFC value will give a benefit compared to a higher TSFC value. In addition, this shows that GP7270 will be more fuel-efficient compare to Trent 970-84 and most airliners are demand engines that more fuel-efficient. From Figure 6, we can see that the TSFC value for Trent 970-84 is higher and the highest is when the aircraft is at altitude 0. Even the lowest TSFC value for Trent 970-84 is still higher than the highest TSFC value for GP7270. As for value, Trent 970-84 lowest TSFC is 19.190 g/(kN*s) while highest TSFC for GP7270 only 13.034 g/(kN*s).

3.3.3 Fuel flow comparison

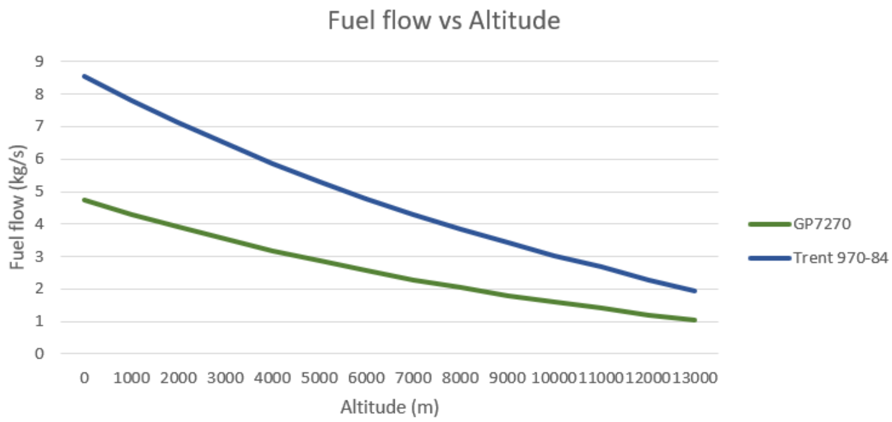


Figure 7: Fuel flow vs altitude graph comparison

Based on the graph in Figure 7, we could clearly state that the fuel flow for Trent 970-84 is higher compare to GP7270. With the value of fuel flow for Trent 970-84 almost two times the value of GP7270, this shows that Trent 970-84 consumes more fuel for the engine. the value of fuel flow for Trent 970-84 at 0 altitudes is 8.538 kg/s while the GP7270 fuel flow at 0 altitude only 4.733 kg/s. However, the value of fuel flow for Trent 970-84 drastically decreases as the altitude increase. On the other hand, the fuel flow value for GP7270 seems to decrease steadily with no drastic changes. At the highest altitude, we could observe that the fuel flow value for Trent 970-84 is almost the same as GP7270 with a value of 1.956 kg/s and 1.027 kg/s respectively.

3.3.4 Propulsive efficiency comparison

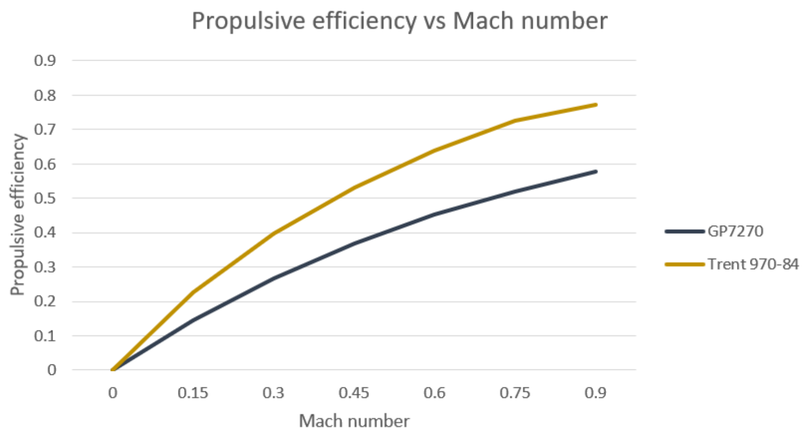


Figure 8: Propulsive efficiency vs Mach number graph comparison

We could see from Figure 8 that the propulsive efficiency for Trent 970-84 is higher than GP7270. This means that the Trent 970-84 is better compare to GP7270 in terms of propulsive efficiency. At Mach 0.9 the propulsive efficiency for Trent 970-84 can be up to 0.7714 while for GP7270 only manage to achieve 0.5781. As the ideal value for propulsive efficiency is 1, this shows that Trent 970-84 operate better than GP7270.

3.4 Summary

From the performance analysis done by using GasTurb software, we could conclude that GP7270 will be more fuel-efficient to be used while Trent 970-84 will produce more thrust. Even though Trent 970-84 produces more thrust, but it also consumes more fuel which is proven by the result of the fuel flow and comparison for both engines. However, in terms of propulsive efficiency, Trent 970-84 seems to be more favorable since it manages to achieve a higher value compared to GP7270. The higher value of propulsive efficiency shows that the mechanical power being converted to propulsive force is high as well. Therefore, we could observe that the thrust generates by Trent 970-84 is higher compare to GP7270. To conclude, GP7270 could be the better engine based on the performance analysis since it is more fuel-efficient and can produce sufficient thrust for the commercial application, with a few improvements such as increasing the bypass ratio, GP7270 could be better than Trent 970-84 where its propulsive efficiency can be increased.

4. Conclusion

The study is focused on the performance analysis that is used for commercial applications. The performance analysis being conducted by using GasTurb software. As for this study, performance analysis had been conducted for two turbofan engine, GP7270 and Trent 970-84 which both of it being used for Airbus A380 aircraft. The performance analysis is focused on a few parameters such as thrust, TSFC, Mach number, propulsive efficiency, and fuel flow. Fortunately, the study manages to achieve all the objectives of the study. The first objective was achieved by developing an engine model based on the data obtained for each engine. The second objective was achieved by conducting a performance analysis on both engines which then different performance parameter was discussed. The third objective was achieved by comparing both engines based on the selected parameters, net thrust, TSFC, fuel flow, and propulsive efficiency. To conclude based on the performance analysis and comparison GP7270 will be more favorable for the operation of commercial aircraft since it is more fuel-efficient.

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