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COMPARATIVE ANALYSIS OF AIRCRAFT ENGINES´ NOISE CHARGES

Abstract

Every year engine manufacturers invest billions of euros into research and development of technologies in order to improve aircraft noise performance. The success is represented by quieter and more efficient aircraft that represent greener aviation. This paper deals with two most efficient aircraft all over the world – Airbus A350 XWB and Boeing 787 Dreamliner where authors compare technological aspects related to the engine structure and consequently its efficiency. Moreover, it describes the main differences between these engines and it compares them from the noise point of view. On the other hand it deals with comparison of noise charges related to these aircraft and their operation at Frankfurt/ Main Airport.

INTRODUCTION

For the purpose of our paper, we choose types of aircraft that represent a family of long-range, twin engine wide body jet airlines from different competitive companies in order to stress the different concepts of engine structure. Moreover, we focus on technological advantages of both aircraft and make analysis of used engine types and their advantages from economic and technological efficiency point of view. These results make a support for our consequent analysis of noise factor that plays one of key indicators related to current green aviation. Moreover, we made an analysis related to the noise charges reflected from the use of these two types of aircraft operated at Frankfurt Airport.

1. SELECTED AIRCRAFT ENGINE´S OVERVIEW

For the purpose of this paper we concentrate on engine development in order to discuss new technology that was used for ensuring quieter operations related to green aviation.

Airbus A 350 XWB aircraft represents one of wide body aircraft that shapes the new concept of travelling experience and which overcomes the challenges of volatile fuel prices, matches rising passenger's expectations and addresses increasing environmental processes related to eco-efficiency targets throughout the aerodynamics, design and advanced technologies. Moreover, it contributes its performance with Rolls-Royce Trent XWB engines which have the lowest carbon emissions of any wide body power plant. The most striking of the numerous technological innovations is the chevron, a sawtooth pattern on the trailing edge of the engine's exhaust nozzle. This results in a better mixing of the turbulent shear layer, the stratum of air between the hot, fast exhaust jet from the engine's turbine and the cold bypass stream that flows around or envelops the engine's core. The chevron nozzle considerably reduces pressure fluctuations and consequently the jet noise emitted by the engines [1]

1.1. Rolls – Royce Trent XWB

It is a series of turbofan jet engines that was developed from the Trent 1000 and it was designed especially for Airbus A350 XWB (Figure 1). This engine also covers many advanced manufacturing techniques that lead towards the development of lighter, more capable and efficient engine that will meet operational needs and customer's expectations.

Rolls-Royce Trent XWB offers advantages that cover weight savings of 15% and aerodynamic efficiency improvements via the use of compressor blisk technology1. Also, world-beating levels of performance and noise with reduced operational costs are linked with the latest fan system technologies

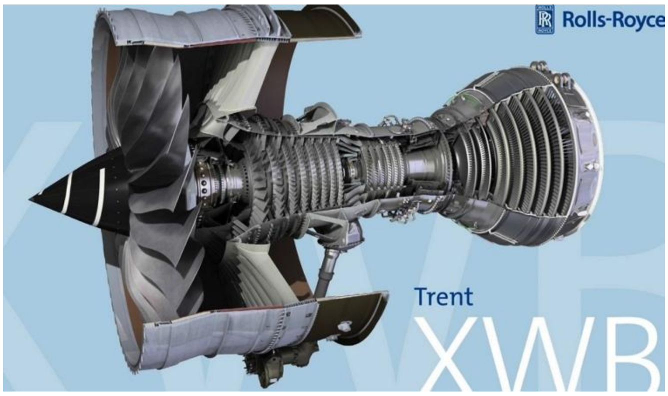

Fig. 1.*Illustration of Trent XWB engine [3]*

Following Table 1, the engine is configured with a three-shaft design and they provide a thrust of 337 kN for the A350-800 and 387 kN for the A350-900. This aircraft also is a quitter thanks to lard part of use of Automatic Noise Abatement Departure Procedure (NADP), which optimises the thrust and flight path to reduce noise over crowded areas.

Tab. 1.*Technical parameters of Rolls-Royce Trent XWB engine [authors]*

Configuration:	Three shaft turbofan
Bypass Ratio:	9.3:1
Overall Pressure Ratio:	50:1
Fan:	22 blades, 118'' diameter
Intermediate Pressure compressor	8 stages
High Pressure Compressor	6 stages
Noise:	QC 1 departures / QC 0,5 arrivals
Intermediate Pressure Turbine:	Dual Stage
Low Pressure Turbine:	6 stages

The A350 XWB is designed as eco-efficient aircraft with lower noise and emissions at every stage of the journey – it is up to 16 decibels below the current standard requirement. Moreover, innova-

[1] Compressor blisk technology – blisk is a single engine component consisting of a rotor disk and blades, the two components it replaces in turbomachinery, which may be either integrally cast, machined from a solid piece of material. Blisks may also be known as integrally bladed rotors [2].

tion and technology are key indicator to provide aircraft that generate fewer emissions and less noise while carrying a maximum payload over the mission range.

1.2. Boeing 787 engines: GEnx-1B

This engine (Figure 2) is a giant leap forward in propulsion technology, using the latest generation materials and design processes to reduce weight, with improvements of performance and also lower maintenance. Advanced technology is based on the high pressure compressor, the twin-annular pre-swirl (TAPS) combustor, and lightweight durable composite materials and specialized coatings. It is the world's first commercial engine with both a front fan case and fan blades made of carbon fibre composite material. This new technology also helps to ensure that all sound of 85 decibels stays within the airport boundaries. Moreover, the noise footprint of the 787 is 60% smaller than today's similarly sized airplanes.

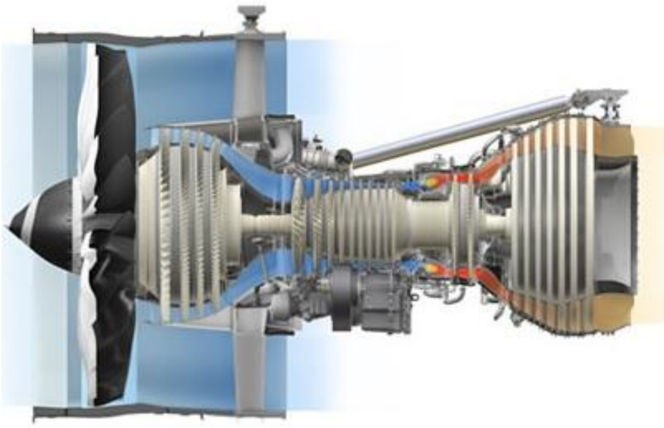

Fig. 2. *Illustration of Dreamliner´s GEnx high bypass turbofan engine [4]*

The GEnx-1B is purpose designed for the Boeing 787 Dreamliner family which is one of most advanced jet engine in service. Technical parameters can be seen in Table 2.

Tab. 2. *Technical parameters of GEnx engine [authors]*

GEnx General Characteristics	-1B70 (B787-8)	-1B74/75 (B787-9)	-1B76 (B787-10)
Take-off thrust	69.800	74.100	76.100
Bypass ratio	9.3	9.1	9.1
Overall pressure ratio	43.8	46.3	47.4
Fan Diameter (in)	111.1"	111.1"	111.1"
Base Engine Length (in)	184.7	184.7	184.7

Moreover, current production of noise meets the London airports' QC/0.5 night noise classification on departure, compared to QC/1 or QC/2 for the 767 or A320. On arrival the 787 is classified as QC/0.25 whilst the 767 and A320 can be classified as QC/0.5 or QC/1.

2. ANALYSIS OF NOISE CHARGES POLICY

Noise Charges are solved according to ICAO's policy contained in Doc 9082/6 (ICAO's Policies on Charges for Airports and Air Navigation Services). This document describes the recommendations and conclusions related to charges in relation to the economic impact on airports and air navigation services provided for international air traffic.

The main reason why this kind of charges exists is based on the fat that it is necessary to minimize the risk of airports and ANSPs engaging in anti-competitive practices and it also tries to avoid any discrimination in the charges application. Moreover, protection of passengers and other airport end-user´s interests is essential.

Noise-related charges should be determined just at airports that experience noise problems and just in the order to recover no more than the costs that applies to their alleviation or prevention. Moreover, this charges should be associated with the landing fee and it should be according to Annex 16 – Environmental Protection related to aircraft noise levels. As it is known, landing charges are based on the aircraft weight formula where the maximum certificated take-off weight can be found in the certificate of airworthiness. Therefore charges can be different due to the policy at congested airports and also during peak periods. [5]

2.1. Day time and night time noise charges at Frankfurt/Main Airport

For the purpose of our paper we decided to research noise charges at Frankurt/Main Airport in order to the fact that we needed to find an airport where both studied aircraft (Airbus A350 and Boeing 787) are operated at. In addition, we also wanted to highlight significant differences between day time and night time charges even in the case of such eco-efficient aircraft.

As was mentioned above, the landing and take-off charge is based on the MTOW of the aircraft. Noise charges are counted per landing and per take-off phase. Also, they are charged with fixed amounts that are setted for each noise category.

Note 1: Allocation of turbo-jet aircraft following ICAO ANNEX 16/3 and 16/4 is divided into sixteen noise categories that can be seen in German AIP (as can be seen in Table 3).

Note 2: For the purpose of our research, we consider just Noise Category 6 [LAX 81,0 bis / to 81.9 dB (A)]where Boeing 787 is part of. Moreover, Boeing 787 is part of Category 6 for landing.

Note 3: Moreover, Boeing 787 is part of different Noise category from the take-off point of vies – it is Category 4 [LAX 79,0 bis / to 79,9 dB(A)] following ICAO ANNEX 16/3 and 16/4.

Tab. 3.*Overview of Noise Categories following ICAO ANNEX 16/3 and 16/4 [6]*

Category	Average noise level at Frankfurt/Main Airport	Category for landing phase	Category for take-off phase
1	to 76.9 dB(A)		
2	77.0 to 77.9 dB(A)		
3	78.0 to 78.9 dB(A)		
4	79.0 to 79.9 dB(A)		B 787
5	80.0 to 80.9 dB(A)		A 350
6	81.0 to 81.9 dB(A)	B 787	
7	82.0 to 82.9 dB(A)	A 350	
8	83.0 to 83.9 dB(A)		
9	84.0 to 84.9 dB(A)		
10	85.0 to 85.9 dB(A)		
11	86.0 to 86.9 dB(A)		
12	87.0 to 87.9 dB(A)		
13	88.0 to 88.9 dB(A)		
14	89.0 to 89.9 dB(A)		
15	90.0 to 90.9 dB(A)		
16	91.0 to 91.9 dB(A)		

Following Table 3 above, we can see that in both flight phases, Boeing B787 is in lower noise category compared to Airbus A350. Even both aircraft are part of the eco-efficient aircraft all over the world, the concept of Boeing 787 is more efficient from the noise point of view.

Table 4 represents noise charges during 24 hours per landing and take-off phase. The amount of charge is in Euro currency.

Tab. 4.*Overview of Noise Charges following German AIP GEN 4.1 [6]*

Category / Noise Charge in EUR															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
43.13	63.79	79.39	98.14	105.57	169.03	353.60	385.91	543.92	592.69	699.58	754.33	1.298.50	1.629.45	2.754.00	22.680

Moreover, we recognise noise surplus charges – Charges for Financing a Passive Noise Abatement Program which have been valid since July 1, 2012. Single noise surcharges related to daytime, night time, passengers or cargo are illustrated in Table 5.

Tab. 5.*Overview of Noise Surcharges according to German AIP [6]*

Time of operation / PAX or Cargo	Noise Surcharge	Validity
DAY TIME	Depends on the noise category of aircraft (1 – 16)	Throughout the entire day (24 hours) per 1 movement in EUR
NIGHT TIME	Aircraft licenced according to ICAO Annex 16/3	A surplus charge has to be paid for movements between 22.00 and 05.59 hours local time
NIGHT TIME	Aircraft licenced according to ICAO Annex 16/2	A surplus charge has to be paid throughout the entire day (24 hours)
PASSENGERS	Per PAX aboard the aircraft when departing	0.24 EUR
CARGO / EMAIL	Per 100 kg or fraction for each movement	0.04 EUR

2.2. Calculations of Noise Charges for each aircraft

All calculations were done by use of input parameters for each selected type of aircraft such as: MTOW and number of passengers.

Note 4: For the purpose of this calculation we take into consideration these flights:

a) B787- 800 (from Frankfurt Airport towards Tokio Haneda Airport flown by All Nipon Airways)
b) A350-900 (from Frankfurt Airport towards JFK Airport by Finnair).

Following Figure 3 we can see noise charge related to 24 hours per landing and take-off phase in EUR for each aircraft.

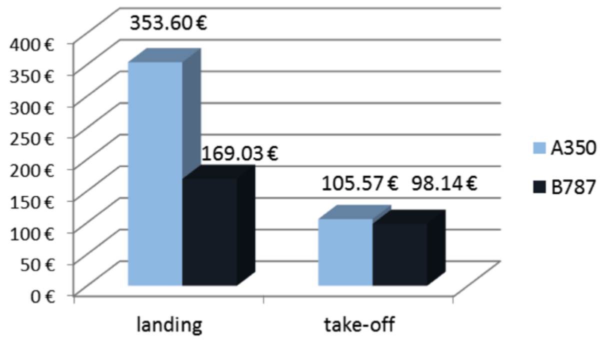

Fig. 3.*Illustration of noise charge during 24 hours for each aircraft [authors]*

As can be seen in Figure 3 above, noise charges were lower for Boeing 787 during landing and take-off phase, too. Mainly during landing phase it is visible significant difference which represents almost 185 EUR per landing. During take-off phase, the difference value was almost negligible (8 EUR per take-off).

As was mentioned in previous subchapter, we also recognise noise surcharge that are different for day time and night time operations phases. These surcharges are illustrated in Table 6 for each aircraft during both flight phases.

Tab. 6. *Overview of Noise Subcharges during day time and night time operations per movement [7]*

Category / Noise Subcharge in EUR – DAY TIME OPERATIONS															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.50	2.25	2.81	3.38	3.75	6.00	12.38	13.13	18.75	20.63	24.38	26.25	45.00	56.25	93.75	750
Category / Noise Charge in EUR															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0.75	1.13	1.41	1.69	1.88	3.00	6.19	6.56	9.38	10.31	12.19	13.13	22.50	28.13	46.88	375.00
Category / Noise Charge in EUR															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
3.00	4.50	5.63	6.75	7.50	12.00	24.75	26.25	37.50	41.25	48.75	52.50	90.00	112.50	187.50	1,500.00

Note 5: The night surplus charge has to be paid per landing and per take-off between 22:00 and 05:59 hours local time. “Night 1” stands for noise surcharge during night time between 22:00 and 22:29 hours and between 5:00 and 5:59 hours in EUR and “Night 2” stands for noise surcharge during night time between 23:00 and 4:59 hours in EUR.

Note 6: Red colour represents charges related to Airbus A350 and blue colour represents Boeing 787.

CONCLUSION

Noise Subcharges defined in German AIP for each type of aircraft operated at Frankfurt Airport had the different values for day time or night time operations in order to protect airport from operational costs and noise restrictions. Following Table 6 we can see that during night time operations bigger values was related to Airbus A350 due to its higher aircraft noise category for both flight phases.

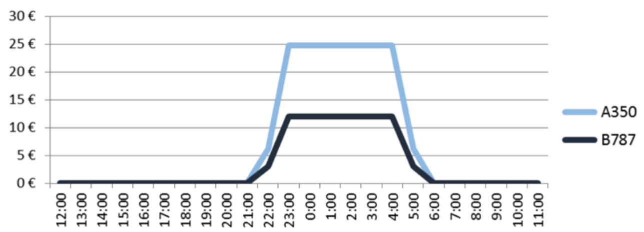

Fig. 4.*Illustration of noise surcharge during night time related to the landing phase in EUR [authors]*

Following Figure 4 above we can see that zero value for noise surcharge was achieved from 12.00 until 21.00 pm in the case of both aircraft. After that Boeing B787 has achieved lower charges compared to A350 (the difference was about 13 EUR per landing from 21.00 until 6.00 am). After that period the noise subcharges were zero value for both aircraft.

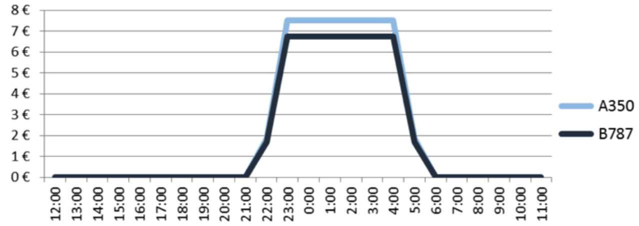

Fig. 5.*Illustration of noise surcharge during night time related to the take-off phase in EUR [authors]*

In the case of take-off phase (Figure 5) we can see that zero value for noise subcharge was achieved from 12.00 until 21.00 pm similarly as in previous case (landing phase). From 21.00 pm until 6.00 am we can see the difference between B787 and A350 was just about 1 EUR per take-off. From 6.00 until 11.00 am it was zero value of noise subcharge for both aircraft.

Briefly, according Figure 4 and Figure 5 we can see that the most visible difference between noise charges was achieved during the landing phase where gap between B787 and A350 was about 8 EUR per landing. During the take-off phase this gap was very small – just 1 EUR per take-off.

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