



POSSIBILITIES OF REDUCING ENVIRONMENTAL IMPACTS OF AIRCRAFT ON MOVEMENT AREAS AND APRONS

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Abstract

This aim of the paper is based on a theoretical analysis of possibilities of reducing fuel consumption, emissions and noise during aircraft take-off, taxi and turn-over procedure. In the very beginning, author defines the basic terms of airport infrastructure and defines types of taxiways based on their constructional solution and physical characteristic. Taxiways are not given to the aircrafts as efficient as possible on many airports. To point out the possibility of reducing fuel consumption and emissions production from different taxiway route, author decided to analyse taxiway and runway infrastructure of Vienna-Schwechat Airport (IATA: VIE) and made runway analysis of Airbus A320-200. Another option how to reduce mentioned attributes and increase the quality of environment is single engine taxi (SET) procedure. Author analysed advantages and disadvantages of SET and established possible communication between aircraft crew and air traffic control officer. Push-back tractors produce not negligible amount of pollutants too. The solution is to operate zero emission push-back tractors powered by electric engine or implement innovative system WheelTug into the nose landing gear. These solutions bring many advantages for surrounding environment and reduce airport noise too. Last not but least, author describes advantages and possibilities of use of Fixed Electrical Ground Power instead of APU or GPU during turn-over procedure.

Keywords

Emission reduction, Environment, Turn-over, Push-back, Taxiing, Derate

1. INTRODUCTION

Nowadays, there is a significant pressure from governments and society to reduce the environmental impact of aviation. The fastest possible step to reduce the adverse environmental impact of aviation on the surrounding environment, given current technologies, is to eliminate fuel consumption by reducing the environmental impact of aircraft on movement areas and airport stands. This will significantly reduce production of emissions. Emissions reduction can be achieved not only through the appropriate method and route of taxiing, but also through the use of modern emission-free technologies during turn-over or push-back procedures.

2. NOISE AND EMISSIONS DURING TAXIING

2.1. Noise pollution and environment

Noise can be understood as an unwanted, disturbing or harmful sound (sound is a vibration) that propagates as an acoustic wave, through a transmission medium such as a gas, liquid or solid. With the increasing intensity of air traffic, which is associated with the growing rate of urbanization in recent decades, there is also an increasing noise pollution in airport areas, which adversely affects the quality of life and health of exposed residents, but also the occurrence of the surrounding fauna. Long-term exposure of noise can cause sleep disorders, has negative effects on the cardiovascular and metabolic system, and also causes cognitive disorders in children. Noise pollution at airports can be reduced by using half of the power

units during taxiing, or by implementing electric engines into airport ground handling vehicles during turn-over and push-back procedures [1].

2.2. Emissions and environment

Emissions produced by aviation account for only 3.77 percent of all emissions in the European Union (in 2017). On the other hand, they have risen by almost 130% in the last twenty years, which is the most significant growth in the entire transport sector. The most abundant compound generated by the combustion of aviation fuel, which has a negative effect on the atmosphere, is carbon dioxide. The decay time of this gas in the atmosphere is about 100 years. Due to its low concentration in the atmosphere, carbon dioxide does not pose a direct risk to human health, but it can cause dizziness, headache, confusion or ringing in the ears [2].

3. FUEL CONSUMPTION DURING TAXIING

The easier way how to calculate fuel consumption during taxiing is to use the procedure set by ICAO. This procedure assumes that average thrust during taxiing is 7% of maximum take-off thrust of the power units. Therefore, this method defines the fuel burn index as the fuel flow at a thrust of 7% of each power unit. Another method of determining fuel consumption during taxiing is to examine the influence of individual factors and divide the taxiing trajectory into individual phases (e.g., constant speed taxiing, stopping, turning, etc.) and assuming a certain power unit setting for each phase and finally interpolating or extrapolating ICAO fuel combustion indices for individual thrust

settings. The sum of the fuel consumption during each individual phase gives the final amount of fuel consumed during taxiing. However, the fuel consumption itself and thus the amount of emissions produced are influenced by other determinants, which impact is unpredictable [3].

3.1. Influence of the most important determinants on fuel consumption during taxiing

Reducing engine thrust during stopping reduces fuel consumption if stopping takes longer time. However, for the aircraft to start moving (taxiing) again, the thrust must be increased again, which is accompanied by a sharp increase of fuel consumption. On the other hand, if the pilot stops the aircraft with the brakes only, without reducing the thrust of the engines, the fuel flow remains high during entire stopping and can lead to a significantly higher amount of total fuel consumed [3].

Fuel consumption and the amount of produced emissions also depend on current visibility. While aircraft taxiing speed generally decreases under reduced visibility conditions, taxiing time over the same distance increases. Therefore, increasing fuel consumption and amount of emissions. Taxiing under reduced visibility increases fuel consumption by 1.5672 times compared to consumption during taxiing under non-significant weather conditions [3].

Whether the aircraft taxiing for take-off (taxi-out) or taxiing to the stand after landing (taxi-in) has also a significant effect on fuel consumption. Globally, it takes almost 52% less time for an aircraft to provide taxi-in than taxi-out. This is mainly due to the push-back procedure and the priority of landing aircraft over take-offs [3].

3.2. Aircraft Communications, Addressing and Reporting System

Aircraft Communication, Addressing and Reporting System (ACARS) is a digital data link system for transmitting messages between aircraft and ground stations. The system automatically delivers a lot of information to the operator during taxiing and the flight, fuel consumption not excluding. Based on the subsequent evaluation of data packets, it would be possible to implement the effectiveness of the established procedures for reducing environmental impacts - we prefer to consider the parameters of consumption during the taxiing, which is the main purpose of this thesis [4].

4. PROPOSAL FOR TAXIING BY SHORTER TRAJECTORY

4.1. Analysis of taxiway and runway system at Vienna-Schwechat Airport (VIE)

To analyze the movements at taxiway and runway system has been selected Vienna-Schwechat Airport. VIE Airport has 159 stands (159 options, but some stands overlap, and therefore the maximum aircraft capacity is 98), 30 taxiways, 18 taxi lines and 4 runways (RWY 11-29 and RWY 16-34). The runway 11-29 has a declared length of TORA of 3500m, and the runway 16-34 has a declared length of TORA of 3600m [5].

4.2. Analysis of Airbus A320-200

The Airbus A320-200 was chosen as the representative for the proposal for the shortened taxiing distance, as it is one of the most frequented type of aircraft operated at VIE airport.

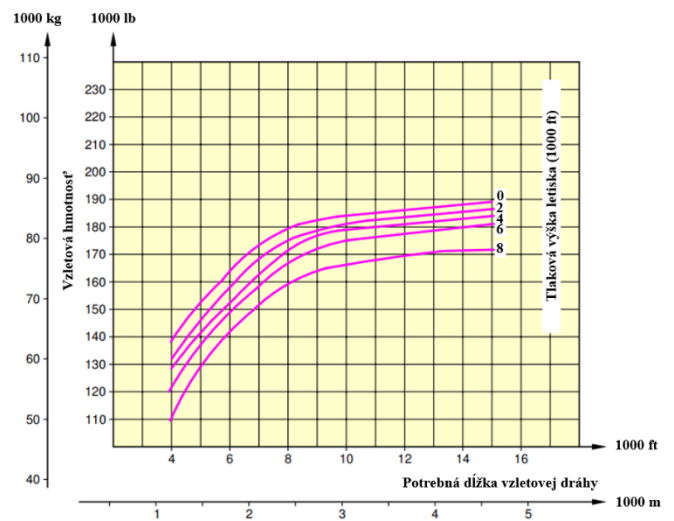


Figure 1: Dependence of the required runway length on the take-off weight under ISA conditions for A320-200 with CFM56-5B power units. [Airbus. 1985. rev. 2020. Aircraft characteristics – airport and maintenance planning, page 146]

If we consider the ISA conditions (Temperature 15°C, Pressure (QNH) 1013.25hPa, Air density 1.225kg/m³), no wind, dry runway, air conditioning - ON and Heating - OFF and wing mechanization set to position 1+F (flaps set to 8.5 ° and slots to 17 °), the required runway length for the Airbus A320-200 at 600ft (VIE altitude) with CFM56-5B power units and weight 70 tons is approximately 1600 meters [6].

4.3. Proposal for taxiing by shorter trajectory from stand F13 to RWY 34

Traditional air carriers often use the entire runway 34 for take-offs. But for take-off under the conditions stated above, the sufficient runway length is 1600m. So, it is not ecological nor economical to use the entire runway length, as it can be entered by multiple taxiways. When determining the possibility of reducing fuel consumption due to the use of a more suitable taxiing trajectory, the average thrust setting of the power units is 7% of their maximum take-off power. When setting a given thrust, the fuel consumption per each power unit is 0.12 kg/s. In the subsequent analysis of the possibility of shortening the trajectory and taxiing time, an average taxiing speed of 15 kts is considered [7].

Fuel consumption during conventional taxiing (Aircraft using all power units) in kilograms, denoted as FB_{Eng} , is given by:

$$FB_{Eng} = t \cdot FF_{idle} \cdot N \quad (1)$$

Where

- FB_{Eng} is amount of fuel consumed by the power units (kg);
- t is time (s);

- FF_{idle} is fuel flow at idle (kg/s);
- N is number of running power units [8].

Assume that the aircraft is parked on stand F13. If the aircraft entered RWY 34 via taxiway B10, TORA would be 2336 meters and TODA would be 2396 meters, which are sufficient distances to execute a safe take-off. Taxiing from stand F13 to RWY 34 and enter RWY via taxiway B10 would save approximately 771 meters of taxiing compared to using the entire length of RWY 34, which at an average taxiing speed of 15 kts represents a time of approximately 100 seconds. This would save 23.98 kg of fuel.

Due to the current take-off weight and weather conditions, the crew of the aircraft could use an even earlier entrance to RWY 34, for example taxiway B8, while TORA and TODA would be 1949 meters long and 2009 meters long. The aircraft save approximately 1396 meters of taxiing compared to using the entire length of RWY 34, which would be approximately 181 seconds at an average taxiing speed of 15 kts. This would save 43.42 kg of fuel.

4.4. Proposal for taxiing by shorter trajectory from stand F13 to RWYs 11, 16 and 19

RWYs 11, 16 and 29 can also be entered via several taxiways. The attached table shows the impact of the use of different entry taxiways on runways in order to shorten the taxiing distance (m), shorten the taxiing time (s) and reduce the amount of fuel consumed (kg). In the analysis, during taxiing both CFM56-5B power units are used on the A320-200 aircraft with an average thrust of 7% of the maximum take-off thrust. Consumption of one power unit for a given configuration is 0.12 kg/s and the average taxiing speed is 15 kts [7].

Table 1: Shortened taxiing trajectories from stand F13. [Authors]

		F13			Skrátená vzdialenosť (m) v porovnaní s využitím vstupnej rolovacej dráhy pri prahu RWY		
RWY	TWY	TORA	TODA	ASDA	Skrátený čas (s)	Ušetrené palivo (kg)	
11	A11	3390	3450	3390	133	4,14	
	A10	3001	3061	3001	487	15,15	
	A9	2458	2518	2458	772	24,01	
	A7	1930	1990	1930	1231	38,29	
29	A2	3404	3464	3404	92	2,86	
	A3	3158	3218	3158	333	10,36	
	A4	2639	2699	2639	495	15,40	
	A6	2116	2176	2116	452	14,06	
16	B2	3470	3530	3470	232	7,22	
	B4	2482	2542	2482	41	1,28	
	B5	2219	2279	2219	-	-	
34	B7	1806	1866	1806	-	-	
	B11	3448	3508	3448	111	3,45	
	B10	2336	2396	2336	771	23,98	
	B8	1949	2009	1949	1396	43,42	

Due to the position of the stand F13 when using the taxiways B5 and B7, a larger amount of fuel will be consumed during the taxiing than using the entire length of the runway. However, from the point of view of performing the flight as an entirety, the aircraft will additionally pass this distance during takeoff. Thus, in the final analysis, it can be stated that from the point of view of the entire flight, the traveled or flown distance will not be saved. If the aircraft enters the runway via taxiway B5 or B7, the power units operate at a higher thrust for a shorter time. This means that even if the taxiing itself takes a longer time and there is more fuel consumed during the taxiing, more fuel should be saved at the take-off phase.

4.5. Possibilities of using Rapid Exit Taxiway after landing

As well as before take-off also after landing, it is possible to select a more or less efficient taxiway for runway vacation. However, in this case, it is not possible to determine unambiguously via which taxiway the aircraft should vacate the runway due to the possibility of shortening the distance and time of taxiing. It is because landing, braking and coasting are affected by a large number of determinants. For example, meteorological conditions, point of touchdown, crew skills, runway contamination or traction reverser application, aerodynamic brakes and landing gear application force.

5. ANALYSIS OF USING HALF OF THE AMOUNT OF POWER UNITS TO REDUCE NOISE AND ECOLOGICAL IMPACTS DURING TAXIING ON MOMENTS AREAS

The main potential benefits of using half of the amount of power units are lower fuel consumption and lower emissions such as carbon emissions, nitrogen oxides (NOx) and unburned hydrocarbons (HC). [9].

The fuel consumed by the APU must also be taken into calculation of total fuel consumption of the aircraft during the SET procedure (SET procedure is a procedure used by twin-engine aircrafts while taxiing with only one active engine). It is essential that the APU is active unless all power units of the aircraft is started-up. APU fuel consumption is significantly lower than one of the power units, but this consumption must also be taken into calculation. Consideration is given by:

$$FB = FB_{Eng} + FB_{APU} \quad (2)$$

Where

- FB total amount of consumed fuel (kg)
- FB_{APU} fuel consumed by APU (kg);
- FB_{Eng} fuel consumed by Power unit [8].

5.1. Comparison of conventional taxiing with SET

For comparison, a model example of taxiing from stand B85 to RWY 34 with entry to the runway via taxiway B10 is performed. The taxied distance is 4332 meters. At a taxiing speed of 15 kts, the aircraft will ride this distance in time of 561 seconds. The push-back time (4 minutes) and the estimated waiting time (2 minutes) must be added to this time. Calculations of fuel consumption during conventional taxiing and taxiing using the SET procedure have shown that the demonstrated taxiing should save 52.78 kg of fuel, which represents approximately 23.87% savings. The calculations also take into account the start-up and warm-up time of the second power unit to operating temperature (ESUT) of 5 minutes.

The savings at the model example did not reach 50%, despite the fact that the aircraft uses SET procedure. The reasons are as follows. If we consider a twin-engine aircraft that uses the SET procedure, to ensure sufficient electricity for the needs of the aircraft on-board system and to ensure the functionality of all hydraulic and ventilation systems (air conditioning), it is necessary to keep the APU in operation, which has its significant consumption [8]. At VIE, using the SET method for taxiing from the stand to the runway could result in an average fuel saving of

18.69%. As the taxiing distance increases, the percentage fuel savings increase.

5.2. Disadvantages of SET

Problems arising during executing a SET procedure are related to excessive exhaust gas flow - Jet Blast. If not all engines are used for taxiing, the remaining engines must generate more thrust in order for the aircraft to move, which causes the danger associated with the force of the air impact generated behind the jet engine. Another problem with twin-engine aircraft during the SET procedure is that asymmetric thrust occurs. Such an asymmetry makes it difficult to turn the aircraft to the side of the running engine [10].

6. POSSIBILITIES OF USING TOWING TRUCK FOR TAXIING

Theoretically, it would be possible to use an electric towing truck to move the aircraft from the stand to the runway holding point. However, we rejected such an aircraft movement process due to the disproportionate safety risk associated with the movement of trucks on taxiways and the high workload of pilots, who would have to verify the functionality of all systems associated with the operation of power units in a short period of time.

7. TAKE-OFF DERATE PROCEDURE

The take-off derate procedure electronically reduces the rated thrust of the engine by one or more specified values, or by a selected percentage of the maximum take-off thrust [11]. Individual operational, meteorological and mass flight data are entered into the flight management system, FMS (Flight Management System), which calculates the speeds V1, VR and V2, and the setting of the thrust of the engines during take-off. In both Airbus and Boeing aircraft, the pilot chooses the derate setting indirectly from a selection of assumed temperatures calculated by FMS. These temperatures correspond to the thrust settings needed to achieve a safe take-off for different take-off weights. In response to the expected increase in temperature, the FMS will reduce the fuel flow to the engine and consequently reduce the thrust generated by the engine [12].

Turbine speed, internal temperature and internal pressure are among the others the most important engine parameters that affect its life. Operating the engine at lower thrust or at reduced thrust reduces the size of these parameters, thereby increasing engine life [12].

The use of reduced thrust during take-off reduces fuel consumption, emissions NOx and BC by 1,0 – 23,2 %, 10,7 – 47,7 % a 49,0 – 71,7 % depending on the aircraft-engine combination compared with 100% setting of power unit thrust (so-called nominal engine thrust). If reduced procedure is not used, total ground fuel consumption is expected to increase, as well as emissions of NOx a BC by 3,3 %, 31,9 %, respectively 71,3 % [13].

8. PUSH-BACK PROCEDURE

Push-back procedure means pushing the aircraft out of the stand using external force, most often in the form of a specialized ground vehicle, called a "push-back tractor" or "tug", in order to get the plane to the taxi lane or taxiway [14].

8.1. Electric push-back

A significant source of pollutants in aviation industry is also those produced by conventional push-back vehicles using diesel engines. Such push-back methods are responsible for 9.5% of nitrogen oxide (NOx) and PM emissions produced by the airport's ground handling vehicles. The approximate fuel consumption of a conventional push-back vehicle with an internal combustion engine at an engine torque of 300 Nm and an engine speed of 2000 rpm is 16 l/h [15].

In order for air transport to be able to maintain its sustainable development and competitiveness, especially with regard to high-speed rail transport, it is necessary to reduce emissions, preferably to zero. One of the parts of aviation where it is possible to reduce emissions due to today's technology is the push-back process.

While diesel engines produce a significant amount of noise, electric motors are very quiet. This contributes to improving the working environment and passenger comfort.

8.1.1. Electric push-back at Munich Airport

In 2021, Munich Airport began renewing its push-back tractor fleet. Conventional push-back vehicles powered by diesel engines are gradually being replaced by »PHOENIX« E vehicles from the Goldhofer workshop. The vehicle uses a modular battery expansion system, which means that the basic battery has a capacity of 66 kWh, while its capacity can be expanded by other battery modules up to a capacity of 165 kWh. If the vehicle uses 165 kWh batteries, it can perform up to 15 push-backs on a single charge. Charging the vehicle's battery from 20% capacity to 80% capacity takes about 30 minutes thanks to using fast charging technology. Thanks to the use of fast charging technology, vehicle can be recharged in a short time, so they can be efficiently charged outside rush-hours, when a lower number of push-back vehicles is sufficient for the needs of the operation. [16].

The type of charging connector is selectable according to operator's preferences and according to the existing electrical infrastructure at the airport, which contributes to saving the operator considerable costs [16].

8.2. WheelTug System

The idea of WheelTug system is to use high-performance electric motors installed into the front undercarriage leg. The system allows not only the movement of the aircraft backwards but also forwards. WheelTug replaces conventional push-back vehicles needed to push an aircraft out of the stand [17].

8.2.1. WheelTug system composition

The basis of the WheelTug system are two asynchronous electric motors integrated into the front undercarriage leg, and thus become part of it. Electric motors are relatively small, but they can still develop a large torque moment, thus ensuring the required traction. The required electrical energy for WheelTug is taken from the auxiliary power unit - APU. Inverters are another important part of the system. The main task of the inverters is to adapt the electrical energy from the APU to that which is needed to drive the electric motors. The inverters also serve as a control unit for the electric motors, protecting the

electric motors from damage at high speeds or skidding. Such protection is provided by power regulation and subsequent disconnection of the stator and rotor parts, based on a signal from a load sensor located on the chassis. The last physical part of the system is the control panel installed in the cockpit of the aircraft. The control panel allows the crew to activate the system and select the desired operating mode [17].

In addition to the physical components, the WheelTug system also contains software on which the correct functioning of the entire system depends. In addition to managing the individual components of the system, the software collects data on its use, and thanks to this, the entire WheelTug system can be constantly improved and optimized [17].

8.2.2. Time and economical aspect of using the WheelTug system

In terms of time, the primary advantage is that the aircraft requesting push-back does not have to wait for a ground service vehicle. Thanks to the WheelTug system, the aircraft can perform its own push-back and is not necessary to unnecessarily wait at the stand. Also, the number of steps performed during the push-back is reduced [18].

8.2.3. Noise aspect of using the WheelTug system

The only significant source of noise is APU activity. However, the noise level produced by the APU is significantly lower than the amount of noise produced by the main power units. If the aerodrome operating time is limited during night, as soon as the Night Curfew ceases to apply, the aircraft can be ready at the runway area and start starting-up the power units. The aircraft can perform push-back and start taxiing during the night noise limit, as the use of the WheelTug system does not exceed the night noise limits [17].

8.3. Mototok – Spacer

It is a small electric vehicle powered by two electrically controlled electric motors. Electric motors are driven by accumulators, while traction accumulators with positive armor plates of the PzS and PzB type or AGM accumulators with LifeGrid technology are used. The batteries provide the device with a voltage of 80 V and their nominal capacity is 300 Ah, which is enough for 30 to 50 push-backs, depends on the weight of the aircraft and the traveled distance. Subsequently, the batteries must be recharged. The charging time is 3 hours. A charging time of 3 hours is sufficient to be able to recharge the Spacer outside of Rush Hours [19].

As this is an electric-powered vehicle, fuel consumption is zero and therefore the vehicle produces zero emissions and is carbon free. It also provides a lower noise compared to conventional push-back vehicles, as it does not have an internal combustion or petrol engine. Other undeniable advantages include its small size and the possibility of service by one staff member only [19].

9. POSSIBILITIES OF REDUCING EMISSIONS PRODUCED DURING TURN-OVER PROCEDURE

The turn-over procedure is a procedure at the airport stand from the moment of stop of the aircraft at the stand to the push-back procedure. The turn-over procedure most often consists of

disembarking and embarking passengers, unloading and loading luggage and cargo, refueling, cleaning the interior of the aircraft, replenishing the catering and powering the aircraft with electricity [20].

9.1. Ground Power Unit – GPU

One of the most widely used methods of supplying electricity to the aircraft's on-board power grid during the turn-over procedure is to use a GPU.

The GPU can be understood as an electricity generator, which is most often powered by a diesel engine. To ensure GPU compatibility with different types of aircraft, it is essential that the GPU be able to provide both DC and AC power. The GPU provides 28 VDC as standard for general aviation aircraft, turboprop aircraft and smaller jets, or 115 V AC with 400 Hz for large commercial airliners [21].

9.1.1. Comparison of APU and GPU fuel consumption

The average fuel consumption of a medium-haul airliner APU is 0.032 kg per second and a long-haul airliner is 0.073 kg per second, which is 115 to 263 kg of fuel per hour. The average consumption of a conventional diesel GPU is from 25 to 35 kg of fuel per hour. Due to the significantly lower fuel consumption, the GPU is used to ensure the supply of the required electricity for the aircraft during the turn-over procedure. However, using of GPU accounts for up to 42% of emissions produced during the turn-over procedure. The APU is used only exceptionally, in cases when the GPU is not available at the airport [22].

9.2. One GPU for two aircrafts

One of the possibilities how to reduce fuel consumption and emissions is to use a special GPU that can provide electricity for two aircraft at the same time. Such a GPU is, for example, the ITW GSE 4400 Diesel GPU. This GPU is capable of supplying 28.5V DC or 115V AC and 400Hz or both at the same time [23].

If two aircraft are to be powered from one GPU, they must stand on the stands next to each other, which is a complication in terms of allocating stands to the aircraft. The ideal allocation of stands would be such that a pair of aircraft with similar time-in and time-out stands next to each other, i.e., the times between which the aircraft stands on the stand.

9.3. eGPU – Electric GPU

eGPU can be understood as a kind of portable accumulator that is charged on one place from a fixed electrical network and then provides its energy to aircraft during turn-over procedure. The representative of such a GPU is the ITW GSE 7400 eGPU [22].

While airport staff, crew and passengers benefit from zero emissions and low noise near the aircraft, the eGPU has a short return on investment due to lower electricity prices and lower maintenance costs, as eGPUs do not have any moving parts that are subject to considerable wear and tear [22].

The use of eGPU compared to a conventional GPU with daily operation of 5.5 hours, for a period of 1 year achieves an overall reduction of CO₂ emissions by 90% and NO_x emissions by 95% [22].

eGPU ITW GSE 7400 is powered by Nissan Leaf batteries with a capacity of 40 kWh for the 28 VDC and 90 kVA 400 Hz versions, and a capacity of 62 kWh for the 140/180 kVA 400 Hz version. Battery life depends on the type of aircraft to which the electricity is provided and on the air carrier itself. For example, some carriers execute shorter but more energy-intensive turn-over procedures, while others execute longer but less energy-intensive turn-over procedures. In a rough estimate, the manufacturer states that the batteries last 6 to 10 hours in a version providing 90 kVA and 400 Hz alternating current with a battery capacity of 40 kWh [22].

9.4. FEGP – Fixed Electrical Ground Power

FEGP is an ecological ground-based energy system that allows aircraft to connect directly to a fixed electrical power source when stopped at a stand equipped with such a system. The FEGP system is directly connected to a conventional electrical network that supplies 50 Hz AC, but 400 Hz is required to power the aircraft. For this reason, the system has three rotary converters, each of which is switched on or off depending on the demand at the stands [24].

The electricity itself can be supplied via the cable system either via the airbridge, via cable winding devices that can be wound as required, using an "alligator cable carrier", or via a system of holes built in the terminal apron area's ground (PIT). PIT system is being used more and more often, because it enables to use a FEGP even on remote stands [24].

Building a system of holes in the terminal apron area's ground is the costliest operation, due to the need for underground power cables, but it provides the highest level of safety and access to such a system can be provided even at remote sites [24].

9.5. Pre-conditioned Air System

A PCA system is often built together with the FEGP system. It is a system of pre-conditioned air adapted for cooling, ventilation and heating of aircraft cabin during the turn-over procedure [25].

There is an AHU (Air Handling Unit) at the stand. AHU is an air handling unit, i.e., a compressor-air conditioning unit that filters, compresses, cools or heats ambient air. Such air is then blown into the aircraft cabin via an insulated duct [25].

Due to the external supply of pre-conditioned air, the aircraft does not have to have the APU running. PCA systems are significantly quieter during operation and reduce fuel consumption and related CO₂ emissions [25].

10. CONCLUSION

Based on the performed analyzes and analyzes of the possibility of taxiing trajectories, taxiing method and take-off derate procedure, it can be stated that to reduce fuel consumption and produced emissions, steps such as shortening the distance traveled by taxiing, use a more suitable taxiing trajectory, execute SET procedure, use of the take-off derate procedure.

In most cases, the use of an earlier (more suitable) taxiway to enter the runway is justified. The aircraft does not have to cross the route in addition, thus saving fuel and reducing emissions. However, depending on the relative position of the stand and

the runway, there may be a case where the use of a taxiway that provides a shorter TORA may not lead to a reduction of the produced emissions. Based on the analysis of the VIE airport (three stands selected (B85, F13 and F26)) and the A320-200 aircraft with CFM56-5B power units, it can be stated that using a more suitable taxiway can save 16.41 kg of fuel on average, with a median value of 14.06 kg of fuel.

Analysis of the same input elements by SET procedure, has shown that such taxiing at VIE airport leads to an average fuel saving of 18.69%, with a median of 18.95%. In addition to the reduced amount of fuel consumed, there is also a reduction in emissions and noise at airport movement areas. However, the crew is exposed to a higher workload during this type of taxiing and must take into consideration the thrust asymmetry and the higher Jet Blast.

It is also necessary to introduce modern emission-free systems such as Phoenix E or Spacer for the push-back procedure. However, airport operators will have to carry out feasibility studies, as the implementation of such electrical systems will require the construction of charging stations and electrical infrastructure. In addition, it is necessary to consider their charging time and possibly the increased number of vehicles compared to conventional vehicles. On the contrary, the WheelTug system does not bring the described problem, so from the point of view of the airport operator, its implementation is more advantageous. However, the operation of the APU is necessary for its functionality, so it is not an emission-free push-back principle.

The GPU produces up to 42% of the total emissions produced during the turn-over procedure, so its replacement is necessary. The FEGP system, which is clearly the most environmentally friendly system, seems to be the most appropriate. Its construction requires high investment costs, especially for its construction on remote stands. The use of individual systems and procedures will ensure, in particular, the improvement of the environment around airports and the reduction of noise pollution. Last but not least, the carriers themselves can also benefit from such methods, in the form of saved financial costs for fuel and in the form of saved time.

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