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RESULTS OF USING SUSTAINABLE AVIATION FUEL IN TRANSPORT AIRCRAFT ON DIFFERENT FLIGHT LEVELS AND THEIR INFLUENCE ON CARBON-DIOXIDE CO_2 EMISSIONS

Summary. During the recent 40 years, the quantity of energy sources globally has been reduced, and the consequence of this situation that the oil in the world becomes more expensive. Many manufacturers have been forced to initiate the development of completely new concepts of developing commercial aircraft which would be more rational regarding fuel consumption by completely retaining the best quality of passenger services. A continuous uptrend of the propellant cost globally since 1990s has forced not only smaller companies but also the most powerful enterprises in aviation industry, such as the “General Electric”, to return to the research and development programs of Turbo Prop engines. In the case of the aircraft DHC Dash 8 Q 400, the engineering preparation of the flight for calculating the changes of travel propellant while the switch of the flight altitude was being done. By analyzing nine various levels of flight, the conclusion has been indisputably reached that regardless of the vast altitudes of a flight and the horizontal distance covered during climb and descent, the fuel consumption is significantly lower than while flying at much lower altitudes with much lower

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horizontal distance in climb and descent. All the indicators that have been reached undeniably confirm the fact that a flight at great altitudes enables lower consumption of fuel and less necessary time of the flights. By such analysis and setting sustainable aircraft fuels into equations, numerous improvements in the world of aviation, which directly influence the quality of life on the global level, are achieved. Likewise, it will indicate the possibility of substitution of classical hydrocarbon (fossil) fuels with biofuels which, while burning, release much lower emission of exhaust gases.

Keywords: sustainable aviation fuel, flight level, carbon-dioxide, turbo prop aircraft

1. INTRODUCTION

During the recent 40 years, the quantity of energy sources globally has been reduced; it has particularly been related to the fact the oil cost becoming more expensive. The deficiency of oil derivatives has influenced the occurrence of new fuels in aviation industry called sustainable aviation fuel, abbreviated – SAF. That has forced many manufacturers to initiate the development of completely new concepts of commercial aircraft which would be, by consuming propellant, rational in higher extent in retaining the best quality of passenger service. Nowadays circumstances with the propellant cost in the world cause that the strongest enterprises in aviation, such as the “General Electric”, determine to go back to the programs of research and development of Turbo Prop engines for aircraft.

The president of the GE for the infrastructure development, John Rice, confirmed that they would work on the development of new generation of turbo prop engines which would respond the requirements of the manufacturers of these aircraft that, beside the rationality in exploitation, must fulfill the following requirements: improved working range, improved operative flight altitude, but also reduced noise, especially in passenger cabins. The strategic partner in the improvement of the project of the new device has been discovered in the Czech Republic, i.e., at the engine manufacturer “Walter Engines”. It is not difficult to conclude the results of this cooperation.[1]

The increased demand for turbo prop engines, which is current all over the world, will be difficult to overcome in due course, at least until greater investments in the segment of development of turbo prop technology are done. The business moves of the “General Electric” and making the decision about the integration with the “Walter Engines” clearly explains that in the foreseeable future, there will appear the engine which will enable the development of greater turbo-prop aircraft in the c 90-passengers category, which is the projected optimum for regional traffic.

Just based on the aforementioned facts, in this project, the determining of propellant use for the plane DHC Dash 8 Q 400, which is an exact example of turbo prop airplanes in district transport of new generation, will be elaborated. These calculations will be conducted as the part of the broader assumed flight envelope, working out all the prescribed variables of a process of flying. The obtained data will be compared with modern requirements for using sustainable fuel in aviation and reducing the emission of carbon dioxide.

2. EXPERIMENTAL

The main determinant of energetic consumption of an aircraft is resistance, to which thrust must be countered in order for the aircraft to maintain a progressive flight. Resistance is proportional to the climb necessary to maintain the altitude, which matches the airplane's mass. As the provoked resistance rises when the mass rises, reducing the mass, improving the motor efficiency, and lowering aerodynamic resistance, eliminating energy waste of an aircraft can be evident, which would be approximately the amount of 1% of mass reduction, and that is 0,75% fuel consumption reducing.[2]

Without doubt, the thesis shows that the airplane flight altitude has the impact no overall functioning of the engine. Essentially, the function of a prop drive increases with the flight altitude increasing up to the tropopause, where the atmospheric temperature is the lowest. Apparently, in comparison with the findings of experimental exploration, the prop engine productivity is higher with the increasing of speed up to approximately 0,85M because of which the losses for the purpose of aerodynamic structure of an aircraft are increasing faster.[3] This value of the Mach number is exceptionally significant because with the beginning of supersonic velocities which on certain parts of the aircraft might occur at the speed of about 0,85M, impact waves cause higher resistance. Because of these facts, during a supersonic flight, it can be difficult to reach the special relation climb/resistance higher than 5 ft that is known according to the research Consequently, fuel consumption increases proportionally for these reasons.

If we directly compare turbojet drive to jet drive, we find that propfan propulsion offers higher productivity. It is confirmed that fanjet engines [4] with a propeller have the optimum velocity of 700 km/h when this speed is lower than the speed of jet aircraft, which are used by many companies in this period. We are acquainted with the rule that if we lower velocity of an aircraft, the resistance will also be reduced. With the continuous increase in jet fuel prices and the growing emphasis on engine and structural efficiency, as well as the need to reduce emissions in the air, the concept of propfan-powered regional aircraft has regained popularity.Based on that , it is believed that it is possible to make a substitute of jet engines with turbo prop engines on medium lines, which would provide positive economic effects for air companies and have an important influence on reducing the quantity of polluting gases emitted into the atmosphere. It is believed that higher levels of a flight result in lower fuel consumption throughout a flight. Also, it is supposed on the basis of so far known characteristics, that turbo prop engines are far more economical and have a much lower degree of noise, and are far lower polluters than turbojet engines.

Further in the thesis, the influence of the height of flying to the needed travel propellant and the period of flying of flight turbo prop aircraft De Havilland Canada DHC Dash 8 Q 400 [5] will be analyzed as well as the analysis of the influence of using sustainable aviation fuels to reduce the emission of carbon dioxide (CO_2) during a flight.

The development of sustainable aviation fuel and its use: As it is already known, global supplies of oil are constantly being reduced, and the relative price of oil is growing, so, according to some estimations, this resource, until the middle of the 21st century, will not be considered as a commercial product. The sources of oil on the global level are estimated to last about 50 more years, so because of that, nowadays, the use of biomass is seriously considered, especially in the sense of obtaining biofuel. More and more countries all over the world gradually increase the percent of biofuel in the mixture with fossil fuel and in that way, they creating new policies of supplying.

All over the world, the focus is on the development of new technologies and procedures for producing biofuels from biomass. Placing by-products of the production of biofuels is also very important for final economic efficiency of biofuel. For example, glycerin which is created during the production of biodiesel can be purified to pharmaceutical quality and the by-products of the production of bioethanol can be used as fodder enriched with proteins. Currently, in the biofuel market, biodiesel and bioethanol dominate.

Biodiesel is an ecological energy source obtained from plant oil, with multiple benefits and advantages related to classical types of fuel. By using it, it reduces the emission of gasses and prevents the creation of the greenhouse effect. By combusting biodiesel, carbon-dioxide, which is neutral, is obtained. Biodiesel does not contain sulfur, lead, or nitrogen compounds. It combusts better in the engine. Because it is biodegradable, and by its use, the pollution of air, water and human environment would be reduced by 300 percent. And the by-products which are formed during the production of biodiesel (glycerin, fatty acids, lecithin) can also be valued, by which the necessity for their import is reduced. Glycerin is used to produce ecological agents for engine cooling, and it also has multiple applications in the pharmaceutical industry and the cosmetics industry. Biodiesel consists of raw materials which are not toxic, i.e., which are degradable and renewable.

The standard procedure for producing biodiesel is the transesterification of plant oil. During the years 2006/2007 8,9 million of tons of biodiesel were produced in the world, of which 64% were produced in the European Union, and 11% in the United States.

The advantages of biodiesel fuel comparing to diesel are: [7]

- Technical aspects: It provides better ignition and lubrication of an engine which means greater efficiency and durability; Safer for keeping and handling: the point of ignition is about 150ºC- while of the fossil fuel is about 70ºC; It does not demand alterations to engines; It is not necessary to change transport and storage systems for using biodiesel.
- Ecological aspects: Reduced emission of gases of greenhouse, particles, and aromatics such as: CO_2, CO, SO_2, NO_2, char, benzene, toluene; Non-toxic; Biodegradable.
- Energetic aspects: Basic raw materials renewable and using already used edible oils and fats; it reduces the necessity for importing oil and risks in supply.
- Economic aspects (on the macroeconomic level, the development of biodiesel production affects the following indicators): Employment; Increasing industry production; Additional overflow of funds to agriculture; Contribution to the development of economy in rural areas; Increasing the reserves of foreign currencies; Reducing the dependence of energetic parameter on external factors.

Since 2004, the production of bioethanol as fuel has been accelerated. During the year 2007, about 40 million m^3 bioethanol was produced in the world. Brazil is the leading world's manufacturer of bioethanol from sugar cane.

The expenses of the biofuel production and requirements for competition affect the prices of agricultural raw materials. Besides the increase in efficiency in the conversion of raw materials into fuels, the introduction of new raw materials will also generally stimulate the use of biofuels. Raw materials which are used in the production of biofuel are used to produce food, by which the prices of raw materials increase and with them the expenses of the production, too. That is why, in cooperation with the researchers, the second generation of biofuel has been produced. The development of the second generation of biofuel is still in its early phases.

Air quality estimation - Air quality in most environments is regulated by the combination of national, regional, and local laws, which set the standards of sources of harmful gas emission and allowed quantity of pollutants and define the ways and procedures for achieving these standards.

Two main areas in the estimation of air quality are the registers of emissions and model of distribution of pollution concentration. The registration of the emissions gives the total mass of the released emissions and provides the basis for reports, adjustments, planning, and reduction and can be used as the input data for pollution concentration modeling. To connect the emissions with the pollution concentrations, it is necessary to process and measure space and time distribution of gases. Such a combined approach of using the registrations of emissions and models of distribution of the concentrations of pollution enables the estimation of the past, current and future pollution near airports or of individual sources. [8]

In 1963, the Government of the United States established the Environmental Protecting Agency – U.S. EPA, and in 1971 it published the National Ambient Air Quality – NAAQS, which covers six polluters CO, Pb, O_3, NO_2, SO_2 and PM10, but also PM2.5.[8]

Standards and regulations which relate to the emission of harmful gas of aviation engines: Currently, standards and regulations which deal with aircraft and other emitters at airports are divided into two categories: measures which set the limits to certain sources of emissions. This also relates to the ICAO standards of engine emissions (the way they are adopted by national and international regulations) and to the nationally established limits for other non-aviation sources such as stationary units and road vehicles; national regulations (or standards) which determine the concentration of pollutants for a certain air quality (limit values of the LAQ).

It is important to make this difference because although all the individual sources can be in allowed limits, the total concentration of harmful gases may exceed the allowed values. Such a situation can occur due to various factors typical for a certain location, including the scope of road traffic, air traffic, and topography, short time meteorological conditions, being near other sources or areas of high concentration of pollutants.

Operative measures - the ICAO supports the development of operative measures and improvement of flight control (Air Traffic Management – ATM) [9] for the aim of reducing harmful gas emission. The most important ways of reducing the consumption are by the ATM systems, which would enable the use of direct routes and optimum heights and speeds, which would significantly reduce the emission of CO_2. According to the research of the IPCC, these improvements would reduce fuel consumption between 8-18%.[10] Some flows were noticed, i.e., the problems in the current ATM systems- waiting for approval for landing in holding, non-efficient routs, non-optimum profiles of a flight. In this research, some more possibilities for the reduction of fuel consumption have been stated- increasing load factor- LF by transporting greater quantities of goods or larger number of passengers, reducing the mass of equipment, which is not necessary, by optimizing the aircraft speed, limiting the use of APU, shortening the taxing. In this way, the consumption would be reduced for an additional 2-6%. Currently, the most efficient way of reducing the CO_2 emission is by reducing fuel consumption. In average, every minute of flight 160 kg of CO_2 is emitted. Every kilogram of spared fuel reduces the emission by 3,16 kg. Constant renewal of fleets and increasing Lf are the most frequent ways of reducing the consumption by companies. The IATA has issued the Guidance Material and Best Practices for Fuel and Environmental Management, in which there are the solutions and possibilities for weight saving, planning spare fuel, optimizing aircraft flight. Additionally, in cooperation with ICAO and flight control service providers, the IATA also works on optimizing routes. During the year 2006, 350 routes in Africa, North and South America, Asia and Europe were optimized which saved 6.000.000 tons of CO_2 emissions. [11]

Market measures- Until the year 1998, all the measures for reducing the emissions were technological, since then market-based measures – MBMs have been introduced [12] as the way of mitigation, limiting and reduction of the emissions. These measures include emission trade – system of trade of emission supposes that the final total allowed quantity of the emitted

CO_2 has been determined and by that it has been established the market which enables the participants to buy and sell their quantities of CO_2 for the price formed by the market. If a participant needs a greater quantity of CO_2, the participant will be able to buy from the others a certain quantity if these participants form lower quantities of CO_2 emission than they are allowed to, before anybody undertakes some of expensive measures for emission reducing. The influence of this principle no ecology has been determined by the total allowed quantity of the emitted CO_2, while the economic influence has been determined by the price of the surplus/ quantities.

Environmental tax- environmental taxes relate to the taxes and contributions that are meant to help the economy reduce emissions. [12] As the base of this contribution, the expenses for transporters are raised, who transfer that to passengers. That can cause reduced demand and in that way the quantity of emissions. On the other hand, they can accept the measures for reduction when it is cheaper than paying taxes. In this case, the economic impact is determined by the amount of the tax, and the ecological influence is determined by how much the tax will affect the acceptance of measures to reduce emissions. The fees included are related to the tax on fuel and the tax on emissions on a route. There are also voluntary measures- these measures represent a unilateral action of industry or an agreement between industry and government for reducing emissions. They can be related to voluntary trade with emissions, compensation for carbon, operative changes, and technological investments.

Alternative fuels - Alternative fuels in aviation do not represent a new concept. Care for the environment is not the main initiator of the interest in alternative fuels; it is their constantly raising price to the extent that it creates losses, i.e., annuls the salary in other places. Security and stability of supply, constant growth of demand, availability, independence from geopolitical events, extreme weather conditions are some of the non-ecological reasons for the interest in alternative fuels. The fuels which are currently used in aviation are the mixtures of various carbohydrates, they mostly contain 60% of paraffin, 20 % of kerosene, 20% of aromatic HC and 500 millionths of sulfur. Kerosene and aromatic HC have a higher share of carbon compared to hydrogen, unlike paraffin. That gives them greater volume efficiency, but also includes the elements which create the emissions of the particles- PM in the exhaust pipe. [13]

The search for an efficient resolution in the protection of the ecological system depends on an overall and rich base of knowledge upgraded by modern technology and the tools for modeling in all the relevant areas.

3. RESULTS AND DISCUSSION

The significance of this research is multidimensional, on one hand, its results will have positive effects on the sustainable development of a society through reducing the emission of exhausting gases and noise, and on the other hand, it will contribute to more efficient functioning of air companies through reducing engaged funds used for purchase of aviation fuel with, at the same time, retaining top service and satisfaction of transported passengers and goods. It will also indicate the possibility of substitution- exchange of classical carbohydrate (fossil) fuel with biofuel, which while burning in atmosphere emit far lower emission of exhaust gases.

Based on known characteristics and current scientific knowledge, tit is believed that it is possible to make the substitution of carbohydrate (fossil) fuels with synthetic fuels (biofuels) in aviation.

The aviation industry is responsible for 3 percent of global emission of carbon dioxide (CO_2). To change that, it is necessary to make sustainable aviation fuel, which will reduce the emission of these harmful gases by 85 percent. [14]

Unlike road transport, aircraft still cannot transfer to electric or hybrid propulsion, because of which there should develop sustainable aviation fuel and the special attention should be paid to synthetic kerosene. [15]

During the International Conference on synthetic sustainable aviation fuel, organized by the Ministry of Infrastructure and Water Management of the Netherlands, many innovative ideas regarding the production of synthetic kerosene were presented. Establishing the first commercial factory of sustainable synthetic kerosene in the port of Amsterdam has been planned.

When it is about constructing the factory in Rotterdam for producing synthetic kerosene, carbon dioxide from the port of Rotterdam will be used. The end aim is, until the year 2050, for the European aviation companies, to use synthetic sustainable kerosene for their flights. [16]

A sustainable aviation fuel can be made from carbon dioxide (CO_2), water, green electric energy, used edible oil, communal waste, and biomass, but many finances are needed to make the fuel economically profitable. [17]

In the development center of the company "Shell" in Amsterdam, synthetic kerosene was produced based on carbon dioxide, water and renewable energy of sun and wind. On the "KLM" passenger flight from Amsterdam to Madrid on January 22, 2021, 500 liters of this fuel were consumed.

"I am proud of the fact that the KLM did the first flight during which sustainable synthetic kerosene made of renewable resources was used. The transfer from fossil fuels to renewable alternatives is one of the greatest challenges of the aviation industry. By renewing the fleet, we have already made a big step forward in reducing their carbon impression, but the real difference will occur by using sustainable fuel. Because of that, the KLM has developed the cooperation with numerous partners to assist the development of sustainable synthetic kerosene. This flight demonstrated that we are on the right way"- said Pieter Elbers, the CEO of the KLM.

The advantages of turbo prop engines comparing to jet engines

Many passengers see turbo prop aircraft as old-fashioned and uncomfortable ones compared to regional jet aircrafts, which are more convenient for passengers, and which particularly fly faster and further. But the truth is that turbo prop engines have the advantage in efficiency (lower fuel consumption) and are able to return to widespread use in this era of high fuel prices. At the same time, aviation companies are moving away from regional jet aircraft with 50 seats and moving to bigger aircraft to reduce the expenses per a kilometer. With high fuel prices, a turbo prop aircraft with 70 seats can cost approximately the same as a jet aircraft with 50 seats. [18]

Recent ranking of American aviation companies related to the efficiency of use (consumption) of fuel discovered that the most economic transporter in domestic transport from 2010 to 2012 was Alaska Airlines, partly because its regional partner company Horizon Air in its fleet had a great number of turbo prop aircrafts. In the year 2012, Horizon completely abolished their regional aircraft of the type of Bombardier CRJ-700 for the account of more efficient turbo prop engines, i.e., DHC Dash 8-K400. Contrary to that, American Aviation Company with the lowest fuel consumption had over 40% of their flights done by its competition, America Eagle on smaller regional planes (CRJ-700 and Embraer ERJ-135/140/145). The flight of 500 miles with 80% capacity CRJ-700 combust about 28% more fuel than on K400 per a passed passenger-mile. [19] The difference between the efficiency of fuel of regional aviation companies affected the ranking of their main partners. The best ranked aviation company in this analysis, Alaska Airlines, would lose from the second-best Spirit regarding the efficiency if the use of fuel by the regional partners had been excluded from the analysis.

The efficiency of turbo prop engines is more impressive when it is regarded from the aspect of regional transporter. The used methods in the above study are flexible and can be used for ranking only regional aviation companies, independently of their main partners. Also, the results are obtained according to the results of fuel efficiency (FES- measure of transport service provided for a unit of fuel combustion- in the year 2012). Only those transporters who reported their fuel consumption (and for whose data has not been determined that are incorrect) were included in the analysis.

It is not surprising that the most efficient regional transporters that fly with a greater share of turbo prop aircraft in their fleet are the companies Horizon and Colgan. The least efficient was the company Chautauqua Airlines, which flies with smaller regional planes ERJ-140 with 44 seats and ERJ-145 with 50 seats. The gap between regional partners with the most and the least efficient fuel consumption is the alarming 73.

Some of these problems can be explained by the characteristics of the fleets of air companies. The best performance was realized by the company Horizon, because it disposes with turbo prop aircraft in its fleet, which were on average younger than six years. The worst result was realized by the company Chautauqua Airlines because in its fleet on regional lines it disposes with the aircraft older than ten years. On an average flight, on regional lines, Chautauqua flew with 28 seats less comparing to Embraer. Other factors which could explain the variation in efficiency include adapting the flight length with optimum range of an aircraft for the best performances, routing, speed, engine utilization (for example, one engine taxi) and fuel charging, among all.

It is of essential importance that some great air companies start abolishing smaller jet aircraft which have expressively non-efficient fuel consumption. In December 2013, the company American Airlines ordered 90 jet aircraft with 76 seats (CRJ- 900 and ERJ- 175) bought for their regional partners for substituting smaller aircraft. In the same year, the company SkyWest Airlines became the exclusive purchaser of Embraer 175-E2 with 80 seats with the contracted order of 100 pieces, of which the beginning of realization is expected since this year. The company SkyWest Airlines also ordered 200 new planes Mitsubishi with 90 seats, for regional transport, which can provide over 20% fuel consumption reducing compared to the current regional aircraft. However, it is not expected that even these jet aircraft of the next generation will be competitive by their efficiency to turbo prop engines which are currently used, and it is less probable that they will be competitive with future turbo prop engines with 90 seats and with the engines of the next generation (Pratt & Whitney Canada) - it is also expected that they will bring the improvement in the aspect of fuel consumption reducing of 20%. So far, five manufacturers have proposed the development of turbo prop aircraft with 90 seats for regional lines.

The transfer to more efficient regional aircraft, i.e., bigger turbo prop aircraft, could significantly reduce the expenses and influence that the degree of efficiency should be significantly improved from currently 73% among regional transporters and help in reducing financial and ecological expenses on the market of short-distance flights.

Analyzing the impact of the flying height on propellant spending

According to EASA EU-OPS 1, propellant needed to perform a flight is divided into trip fuel used since the time of initiating the engine at the airport of taking off to the moment of turning off the engines at the destination airport and supplementary propellant used for flying to a substitute airport, waiting and due to navigation errors. The total block fuel necessary for realization of a flight represents a functional dependence on flying distance, i.e., with increase in flying distance; the amount of the needed propellant for travel is linearly increased. In this project, analyzing the impact of the flying height on the needed propellant for travel and the period from FL160 to FL240 with the step 20 will be considered. In addition, the estimation of propellant for travel is explored for the segment of the flight that is "en route", the takeoff is performed with RWY with PA=3.000 ft, landing is performed at RWY with PA=2.000 ft. Meteorology conditions on the complete flight are: ISA+20, headwind 20 kt (kt=1,852 km/h), without turbulence, without the condition for freezing and without importance for various quantities of air moisture, all drives are functional. [5, 20]

- Travel propellant estimation.

This mass includes the fuel needed to complete the takeoff, climb, cruise, descent, supposed travel procedure, and approach and landing at the destination airport. Before every flight, engineering getting ready for flying is performed.[21] Based on the information regarding preparation for flying contained in the Aircraft Operations Instructions for the plane DASH 8-400, the following values are obtained Travel propellant = 2.606,00 kg; Trip time = 2:46 (hr:min).

- Propellant for possible unexpected cases

The fuel is intended for the cases of contingency during a flight, such as: avoiding stormy weather and unpredicted long period of waiting at the approach for landing. Contingency fuel is usually determined in percent compared to trip fuel. It must not be forgotten to calculate this mass of fuel into the landing mass of an airplane. Similarly, we receive the following:

$\Rightarrow$ propellant for possible unexpected cases = travel propellant x 5% (1)
$\Rightarrow$ propellant for possible unexpected cases = 2.606 kg x 0,05 = 130,30 kg

- Substitute (Diversion) propellant

The quantity of fuel can be provided for a possible change of the destination airport, sequential lifting, prolonged procedures of landing approach, navigation errors and so on. For the shown technical issue, a substitute airport is not regarded.

- The rest propellant in the end

That is the smallest amount- mass of propellant that remains in reservoirs during landing. Genuinely, the reserve propellant in the end for unexpected situations ought to be, about, for prop piston airplane flying of 45 minutes, and for jet and turbo prop of 30 minutes, for a determined height and reaching rate. Similarly, we receive the following:

$\Rightarrow$ the rest propellant in the end = travel propellant / travel duration x 0:30 (2)
$\Rightarrow$ end reserve propellant = (2.606,00 kg / 2:46 (hr:min)) x 0:30 = 471,00 kg

- Supplementary propellant

That amount of propellant is projected solely if the number of propellant quantities described in the above paragraphs is lower than the requirements described in EASA EU- OPS 1. Therefore, the entire quantity of travel propellant and period needed to perform flying is:

$\Rightarrow$ entire needed propellant = travel propellant + reserve propellant + end reserve propellant (3)

⇒ entire necessary propellant while taking off = 2.606 kg + 130,30 kg + 471 kg = 3.207,3 kg

Maximum time of the flight duration = 3:16 (hr:min)

According to the values obtained in the previous part for total necessary quantity of propellant to perform flying and based on registered values for dry functioning weight of an airplane DOM, the Transport Cargo TC [5], we have evaluated the entire weight of the airplane while taking off TOM, and got the following:

⇒ zero fuel weight (ZFM) = DOM + TL (4)
⇒ zero fuel weight (ZFM) = 17.268,00 kg + 5.247,00 kg = 22.515,00 kg

Now, we can evaluate the entire takeoff weight of an aircraft:

⇒ takeoff weight (TOM) = ZFM + Propellant (5)
⇒ takeoff weight (TOM) = 22.515,00 kg + 3.207,3 kg = 25.722,30 kg

According to the presented values in calculating the take-off mass of an aircraft TOM from the previous ones, the results we got have been utilized in evaluation so that we get the required values at the horizontal distance, necessary fuels, and time for various regimes of a flight (climb, cruise, and descent) for assigned heights of flaying. To continue analyzing, we need to regulate the modifications of the horizontal height for each of the types of flight by alternating the altitude to the flight height FL160 to FL240.

By using the Aircraft Operations Instruction, we get the following:

- Climbing to FL160

The results of speed evaluation for climbing (Knots indicated air speed) KIAS have been derived from the Aircraft Operations Instruction. The result of calculating the FL160 is 205 KIAS. T That is how we obtain the results of other flight heights to FL240.

Tab. 1

Speed calculation in climb KIAS from FL160 to FL240

FL	160	170	180	190	200	210	220	230	240
KIAS	205	200	195	190	185	180	175	170	165

Based on the information in the Tab. 1, It is noticed that the KIAS rate has dropped for each 1.000 ft of height. Based on the registered criteria in which: Type I type of lifting, a segment of the entire 20, the plane weight is about 26 tons, the plane takes off with the RWY with PA = 3.000 ft and lifts to the height of FL160 (the difference FL160-FL30 is utilized in getting the results from the table), in utilizing the AOM, the results below are obtained for a horizontal length, the period for climbing and needed propellant: Horizontal length: 30,5 NM: Time of lifting: 9 minutes; Needed propellant while lifting: 234 kg.

It has become now possible to obtain the values for changing flight levels from FL160 to FL240 based on identical concept. Alternating the altitude for 1.000 ft, we can find out that the flight period is 1 min and from there comes fact: an aircraft's climb rate of 1.000 fpm, which, based on AOM [5] regarding the stated aircraft, the values complement. Based on AOM [5,20], it is proved that at lower heights an aircraft has a climb speed of 2500-3000 fpm, and rising the altitude the rate is falling. In addition, it has been noticed that the height change and horizontal distance are dependent on with fuel consumption.

In other words, after every 1.000 ft of altitude alternation, linear and horizontal height is changed averagely 4 Nm, and fuel consumption averagely for 18 kg. Such dependence between the results is noticed the best in the graphic presentation on the Fig. 1. [25, 26]

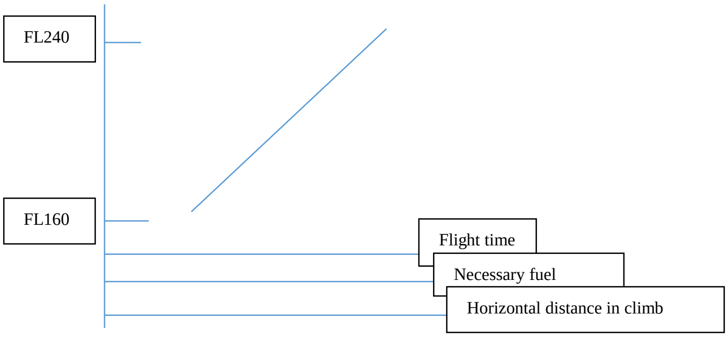

Fig. 1. Dependence between the results, flight level and necessary fuel, flight time and horizontal distance in climb

- Descent with FL160

The values for speed calculation in descent KIAS are obtained based on the AOM. [5, 20] Estimated results of FL160 are 277 KIAS. Thus, the results of other flying heights to in this way the values for other flight levels to FL240 have been achieved.

Tab. 2

Speed calculation in descent KIAS of FL160 to FL240

FL	160	170	180	190	200	210	220	230	240
KIAS	277	277	277	268	260	250	247	243	240

Based on obtained results in Tab. 2, it has been noticed that by changing altitude velocity KIAS the speed KIAS also falls. Velocity fall has not been linearly distributed, but it has been stable regarding flight height FL180, and it has been falling steadily. Because of registered constants such as: Type I is the type of descent, a segment of the entire period of flying 20, plane mass is about 26 tons, the airplane is landing on the RWY with the PA = 2.000 ft height FL160 (it is used the difference FL160-FL20 for getting the results from the table), by utilizing the AOM, we get the results for horizontal height, period of climb, needed propellant: Horizontal height: 34 Nm (Nm – nautical mile, 1 Nm=1.852,00 m), Time of descent: 11 min; Needed propellant in descent: 129 kg. As flying occurs based on the weather, that means ISA +20, it is necessary to do certain correction; ISA +20 are as follows:

- to add 5% to horizontal height,
- to add 6% to needed propellant.

When the results have been corrected, we got as follows: horizontal height: 36 Nm, descent period: 11 min; needed propellant while descending: 137 kg.

Now, results of alternating flight levels may now be obtained from FL160 to FL240, using the same principle. According to the obtained data, it is concluded that with the change of altitude for 1.000 ft, the period of average 2 minutes is needed, implying that the plane descends on rate 500 fpm. With increasing flight level, increasing of horizontal height while descending has not been linearly done, but on smaller altitudes its linearity has been 3 NM, and over FL180 it has been another type of linearity on average 11 Nm every 1.000 ft of altitude. Identical regulation applies to fuel consumption due to its direct proportion to passed horizontal height.

- Cruise on FL160

Utilizing the AOM cruise results of KIAS, KTAS and fuel consumption per a flight hour are obtained. Cruise results for flight level FL160 are KIAS: 211 kt; KTAS: 278 kt; Fuel used during one hour of flight: 878 kg/h

Likewise, by applying the results of AOM by the identical definition, relying on the KIAS alternation on flight altitude, from FL160 to FL240 is obtained. The reliance has been displayed on the Tab. 3.

Tab. 3

Speed calculation KIAS in cruise depending on altitude change of FL160-FL240

FL	160	170	180	190	200	210	220	230	240
KIAS	211	210	209	208	206	203	201	199	197

Based on the content of the Tab. 3, the conclusion can be made that when altitude rises to FL180, velocity KIAS is straightly falling 1 kt every 1.000 ft, and over FL180 the linearity stays the same, each 1.000 ft altitude the velocity KIAS falls for averagely 2 kt.

Besides the data obtained for analyzing KIAS for altitude change, facts of KTAS that alternate, too, with altitude change are significant. Trip speed GS depends on these values, and it is determined based on wind (headwind in entire period of flying 20 kt) and KTAS. Travel velocity of flying height FL160 is:

$\Rightarrow$ GS = TAS +- Wind (6)

$\Rightarrow$ GS(160) = 278kt – 20kt; GS(160) = 258kt

Tab. 4

KTAS and GS values in cruise, presented depending on the change of flight level from FL160-FL240

FL	160	170	180	190	200	210	220	230	240
KIAS	278	281	284	286	289	291	292	294	296
GS	258	261	264	266	269	271	272	274	276

KTAS and GS values, depending on flight altitude, are shown in the Tab.4. By using the data from Table 4 and the values obtained in climb and descend, we obtain the following:

$\Rightarrow$ total distance = horizontal distance in climb + distance in cruise + horizontal distance in descent (7)

$\Rightarrow$ height in cruise (FL160) = 800 Nm – (30,5 Nm + 36 Nm) = 733,5 Nm

By equation (7) there can be obtained the values of distance in cruise for other flight levels.

Tab. 5

Values of horizontal distance in cruise, displayed with the changes of the flight level from FL160-FL240

FL	160	170	180	190	200	210	220	230	240
Hor.dist.	733,5	727	718	704	688,5	672	656	641	627

Based on Tab. 5 there has been observed contrast in horizontal altitudes in cruise with altitude alternation. With altitude, the contrast linearly is falling and has less contrast af flying altitude FL180, and over that altitude there has been observed contrast on 16 Nm on average basis as altitude changes for 1.000 ft.

By utilizing the results derived in the equations (6) and (7), then Tabs 4 and 5, flight period in cruise is the result:

$\Rightarrow$ period of flying in cruise = horizontal altitude / travel velocity (8)

$\Rightarrow$ flight period in cruise (FL160) = 733,5 Nm / 258 Nm/hr = 2,84 hr --> 171,5 min

By equation (8) the results of needed period cruise are obtained at other flight levels, too. For analyzing the period of a flight containing altitude alternation in detail,, the results in Tables 4 and 5 and equation (8) will be utilized in equation (9):

$\Rightarrow$ total flight time = climb time + cruise time + descent time (9)

$\Rightarrow$ total flight time (FL160) = 9 min + 11 min + 171,5 min = 191,5 min --> 3,17 h

By equation (9) the results of necessary period in cruise are obtained for other levels of flight, too.

Tab. 6

Total flight time, displayed with the change of flight level of FL160-FL240

FL	160	170	180	190	200	210	220	230	240
Time	3,17	3,14	3,10	3,08	3,04	3,01	2,99	2,96	2,94

Based on the Tab. 6 there has been observed that, as the height rises, the flight time reduces. Likewise, by analyzing time needed to perform a flight ithas been observed that time of climb and descent is significantly longer for higher flying altitudes; time is immediately related to consumption of drive of an aircraft to get and drop altitude. Principal information that horizontal altitude in cruise is notably smaller on higher altitudes, for the reason of the climb and descent, it is necessary to have more excessive horizontal altitude for more elevated flight altitudes and that the time in climb and descent has not affected the total flight time on more elevated flights flight altitudes to be lower.

In determining needed amount of propellant in cruise, results of AOM and results of Tab. 6 have been utilized:

$\Rightarrow$ fuel amount in cruise = propellant utilization per a flying hour x period of flying (10)

$\Rightarrow$ fuel amount in cruise (FL160) = 878 kg/h x 2,84 h = 2.493,5 kg

By equation (10) the necessary quantities of fuel for cruise are obtained for other levels of Flight. In order to thoroughly analyze the entire amount of propellant needed for flying with altitude changing, values obtained in previous evaluation are going to be utilized in equation (11):

⇒ entire amount of propellant = propellant amount in climb + propellant amount in cruise + propellant amount in descent (11)

⇒ entire amount of propellant (FL160) = 234 kg + 2.493,5 kg + 137 kg = 2.864,5 kg

The results of equation (11) indicate that the entire propellant amount displayed in Table 7 has been gained for various flying altitudes.

Tab. 7

The values of the total quantity of fuel displayed with the change of the flight level of FL160-FL240

FL	160	170	180	190	200	210
Fuel	2.864,5	2.806,2	2.750,3	2.710,2	2.673,7	2.650,9

Based on Tab. 7 there has been observed, by increasing altitude, the entire propellant amount reduces. Likewise, based on propellant needed for flying necessary for a flight, it has been observed that the quantity of needed propellant for climbing and descent is notably vaster for higher flight altitudes; propellant is immediately related to spent energy for the airplane to get and drop the altitude. It is also important to note that during a cruise, it is necessary to have less fuel at higher levels. Although more propellant is needed in climb and descent for more elevated flying altitudes, the alternation is not affected to entire amount of propellant on higher flying altitudes, which is significantly less on smaller flying altitudes.

The influence of fuel consumption no the emission of carbon dioxide CO_2

The influence of air traffic on the environment and climate attracts more and more attention of the public, but also of aviation organization. Exhaust gases from aircraft engines are like those which occur because of burning fossil fuels. Currently, air traffic has relatively little contribution to the “greenhouse effect” but the latest research shows the need for urgent engagement of all the sectors with the aim of reducing total emissions. Air traffic, compared to other types of transport, participates with 3% [24] in the total production of carbon dioxide CO_2 of anthropogenic origin. However, besides carbon dioxide CO_2, as well as other sources of pollution, it emits other gasses and substances which affect the environment. According to the data of the IPCC, at the international conference about climate changes, the participation of the traffic sector in the emission of harmful gases compared to other sectors was displayed, which was presented in the Fig. 2. [23]

The air industry is constantly growing. The expected annual growth rate of air traffic is 5% for the following 20 years, and in some parts of the world, like in East Asia, it is estimated to grow by even 9%. Sustainable development of industry requires the complete estimation of the effect no ecology, both globally and locally. By considering globally, aviation pollution affects climate changes. A climate change is supposed to be every change of climate during time, whether because of natural variation, or because of human activities. Emissions of gases which influence the “greenhouse effect”, as well as CO_2, create positive radiation force, which, as a long-term influence, affect heating of the earth’s surface. There are other, short-term influences, for the reason of creating cirrus clouds, nitrogen oxides NOx and various particles which, also, contribute to global warming. These gases retain heat in the earth's atmosphere and disturb natural climate courses. During the previous century, the temperature grew for 0.74ºC with the trend of growth further in future. It is estimated that in this century it will grow up to 3ºC. Aircraft in most cases fly on cruise altitudes between 8km and 13km. During the flight, they release gases and particles directly to the upper layers of troposphere and lower layers of stratosphere and in that way, they affect and change the structure of the atmosphere and clouds, disturbing the balance of the earth warming radiation.

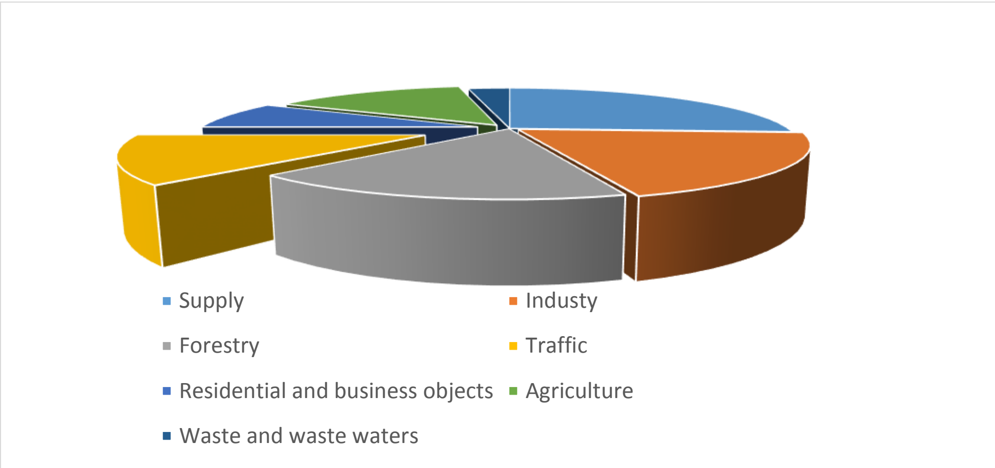

Fig. 2. Participation of the transport sector in harmful gases emission

The cumulative significance of the influence of such emission is hard to be determined. Global climate changes are caused by the accumulation of greenhouse gases in the lower parts of the atmosphere. Precisely, it is about carbon dioxide CO_2, water steam H_2O, nitrogen oxides NO_x, carbon monoxide CO, carbohydrates HC, aerosols- sulfur oxides SO_x and char. According to the results of experts, what is the most worrying is CO_2 and according to the estimations of the ICAO, in the year 2005 600 million tons of CO_2 was released only from air traffic. Air traffic affects the quality, i.e., pollution of local air. These pollution sources do not originate only from aircraft but also from induced traffic around airports, equipment on land for receiving and shipment of aircraft and other emission sources related to airport functioning.

ICAO calculator of carbon dioxide emission CO_2

ICAO [9, 10] as an international organization for civil aviation has been developing for a long time the methods how to calculate the emission of CO_2 that occurred during air transport of passengers and goods. As a result of this, during the summer of 2022, it published the calculator called ICEC (ICAO Carbon Emissions Calculator) as the only one internationally tool approved to calculate expected values of carbon dioxide emission from air transport. The ICEC enables passengers to calculate expected values of carbon dioxide emission during their own trips. As the programmers of ICAO state, the calculator is organized to be simple for using and not to demand too much input information by the users. The methodology applies the best publicly available data from the industry to consider various factors such as the types of aircraft, data specific to routes, factors of passenger load and transported cargo.

The calculator can be used by individuals, private companies, international and non-profit organizations, and organizations of the system of the United Nations to estimate their supplies of carbon dioxide for the purpose of compensating.

To find their own impression of carbon dioxide by using the ICEC calculator on the route of a flight, it is necessary to input the information of the airport of taking off and destination, as well as other information used for buying a ticket with some of the air companies of the desired flight route. Accordingly, if a passenger decides to fly from Belgrade, Republic of Serbia, to the seaside town Tivat in the Republic of Montenegro, one way, economy class, with the total number of 50 passengers, the following results are obtained:

Tab. 8

Calculation of total emission of carbon dioxide on a specific flight and presentation of the expected fuel consumption

A/P Take-off	A/P Dest	Number of passengers	Cabin class	Direction	Burnt fuel / trip (kg)	Total number of passengers CO_2 / trip (kg)
BEG	TIV	50	Economy	One way	1.976,3	2.410,9

In the Tab.8. there can be regarded the values of burnt fuel on the flight between Belgrade and Tivat, as well as the total emission of carbon dioxide CO2 on the flight expressed in Kg. To simplify the results, the values on individual levels are shown in the Tab. 9.

Tab. 9

Calculation of individual emission of carbon dioxide on a specific flight and presentation of the expected fuel consumption

A/P Take-off	A/P Dest	Distance (km)	Aircraft	Burnt fuel / trip (kg)	Passenger CO_2 / trip (kg)
BEG	TIV	296,0	320, 32S, ATR, E95	1.976,3	48,2

The above table provides information regarding the most frequent aircraft routes, as well as the distance, total fuel consumption, and individual carbon dioxide emissions per passenger. In the Tables 10 and 11, the values are given for a longer route: Belgrade-Zagreb in Croatia, calculated for the same number of passengers:

Tab. 10

Calculation of total emission of carbon dioxide on a specific flight and presentation of the expected fuel consumption

A/P Take-off	A/P Dest	Number of passengers	Cabin class	Direction	Burnt fuel / trip (kg)	Passenger CO_2 / trip (kg)
BEG	ZAG	50	Economy	One way	699,5	1.744,2

Tab. 11

Calculation of individual emission of carbon dioxide on a specific flight and presentation of the expected fuel consumption

A/P Take-off	A/P Dest	Distance (km)	Aircrafts	Burnt fuel / trip (kg)	Passenger CO_2/ trip (kg)
BEG	ZAG	346,0	ATR	699,5	34,9

Of the presented values in the Tabs. 10 and 11, the demands of industry are confirmed that turbo prop aircraft on shorter, i.e., regional routes are the future of aviation. On the route Belgrade- Zagreb, the calculator predicts the flight by ATR, a popular turbo prop aircraft in the region (competition at the market DHC Dash 8 Q 400) where for the distance is 50 km longer than on the flight Belgrade- Tivat, 1.276,8 kg less fuel is consumed. Especially important data is the emission of carbon dioxide, which is also drastically reduced, so on the flight to Zagreb, it is now 34,9 kg per a passenger compared to 48,2 kg on a flight to Tivat.

3. CONCLUSION

According to the above - mentioned calculations, the obtained data show that, by comparing the characteristic of the plane DHC 8 Dash 8 Q 400 on different flight altitudes, it is commercially viable (considering the amounts of needed propellant) and in terms of time, rather to select the flight levels on higher altitude than on the lower one. The results show that in the case of the same angle of climb and descent for every flight level, regardless of the fact that the horizontal distance increases proportionally to the increase in the flight level, it is significantly lower consumption in the total quantity of fuel and necessary trip time for a flight than on the lower flight levels.

Issue of energy sources with the comprehension that oil sources become very low, and that besides these facts, new types of fuel have not been discovered yet, during the early years of this century, numerous aviation enterprises, based on calculating- planning trip fuel, has concluded that in regional air traffic, applying jet tourist aircrafts is not commercial. In such situations, prop aircrafts are made convenient for traffic in regions, which provides improved results. An enterprise expects profit gain due to improved flight efficiency. It especially applies to the utilization of propellant .The significance of the results of technical calculations, travel propellant spending by alternating flight level is confirmed by the published information of the air company Malaysia Airlines which, in the May of the year 2013, signed an agreement for three billion dollars to buy 36 ATR 72-600 latest model of that producer leaning on the situation that they, in October, November and December of the year 2012, demonstrated the fall of the profit because they used jet passenger aircraft for regional traffic, while, contrary to that, they had in their fleet 12 ATR 72-500 which made more profit to company in traffic in regions for the same period. According to all the previously presented, it can be concluded that prospective of traffic in regions will be in turbo prop engines due to smaller fuel spending, but also more economical every other feature which is demonstrated through profit when finished.

The results obtained from such a comparison with the use of sustainable aviation fuels demonstrate multiple benefits, including a reduction in fuel consumption, lower operating expenses, and lower carbon dioxide emissions, which are modern requirements and challenges for society The data from the company United Airlines shows that in the year 2019, it used 8,9 billion of dollars only for fuel, i.e., 23% of 38,9 billion of dollars that make up the company's total expenses. As it has been shown, the only greater expenses of 30% are the salaries of employees. That is exactly the reason why the United Airlines initiated, among the first ones in the world, the flights with 100% sustainable aviation fuel and increased the purchase of turbo prop aircrafts more than regional turbojet aircrafts.

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