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INVESTIGATION OF “GREEN” APPROACH TRAJECTORY FOR FULL EXPLOIT OF THE BENEFITS OF SINGLE EUROPEAN SKY

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Abstract. *The article deals with main directions of European Clean Sky concept, investigation of the influence of changing of glide slope angle on the engine operation mode during approach phase, analysis of advantages and disadvantages of changing of glide slope angle.*

Keywords: approach trajectory, Clean Sky concept, engine thrust, glide slope angle.

Introduction

Nowadays aviation industry is highly developed industry. First of all air transport carries over 2.2 billion passengers annually and generates a total of 32 million working places globally. Secondly, aviation's global economic impact is estimated at US\$ 3.560 billion representing 7.5% of world Gross Domestic Product (GDP). At the same time air transport's contribution to the climate change represents 2% of human-induced CO₂ emissions (and 12% of all transport sources). Flights produce 628,000,000 tones of CO₂ yearly. Worldwide, it is estimated that the equivalent of 1300 of new international airports will be required by 2050 with a doubling in the commercial aircraft fleet. This fact can soon lead to the technology catastrophe. So the challenge which is facing aviation is to meet the predicted growth in demand for air travel (increasing 4-5% per annum over the next 20 years) but to do so in a way that ensures that the environment protection.

An integrated and coordinated program

The greening of Aeronautics and Air Transport calls for a quantum leap in performance through a consistent, coherent and holistic approach focusing on the integration of advanced technologies and validation of results in a multidisciplinary approach leading to full-scale ground and flight demonstrators [1].

Technologies have to be concurrently developed, integrated and validated to maximise the benefit of technology interaction and cross fertilisation on the whole Air Transport System (ATS). Those are organised into six main themes, six Integrated

Technology Demonstrators (ITD), that cover the broad range of R&T work: aircraft – fixed wing (large and regional aircraft) and rotorcraft, engines, systems and eco-design concepts able to deliver more environmentally friendly aircraft production and operations. A “technological evaluator” is a set of models to predict the local and global ecological impact of the technologies which is being integrated, and it will allow to conduct independent analysis of the projects as they unfold [1].

ITDs implement technologies which will enable the progress which will be truly groundbreaking rather than “incremental” – since the reductions of about 30% are expected in terms of both carbon emissions and noise. These six themes are not just a simple “package” of programs they are independent to one another. On the contrary, they form a whole and the Joint Undertaking has to be structured in the most efficient way allowing the full coverage of all areas of R&T work while ensuring a high degree of efficiency in the management of the technical activities.

Real life demonstrations are essential components of the Program as they will enable technologies to reach a high level of maturity. This in turn will be essential in order to assess the environmental improvements which are achievable. The following technologies will be demonstrated within the 2013–2016 timeframe:

- Contra Rotating Open Rotor Demo Engine Flying Test Bed;
- High Speed Demonstrator for passive laminar-flow wing technologies;
- Low Speed Demonstrator for advanced control surfaces for high lift;

- Regional Aircraft Integrated Flight Test Demonstration;
- Regional Aircraft Static & Fatigue Full Scale Ground Demonstration;
- Regional Aircraft Large Scale Wind Tunnel Test;
- Rotorcraft lift & drag demonstrators;
- Diesel engine demonstrator for light helicopters;
- Aircraft & Rotocraft Systems Demonstrators;
- Geared Open Rotor Demonstrators;
- Large Three-shaft Engine Demonstrator;
- Advanced Geared Turbofan Demonstrator;
- Advanced Turboshaft Demonstrator.

Main directions of Clean Sky concept

The Clean Sky JTI is one of the largest European research projects, with a budget estimated at €1.6 billion. It is equally shared between the European Commission and industry, for the period 2008–2013. The objective of this unique public-private partnership is to speed up technological breakthrough developments and to shorten the time for the market for new solutions tested on Full Scale Demonstrators.

Speeding up new, greener design is essential to protect our environment. It should be kept in mind that aircraft have a 30-year service life, and it takes more than a decade to develop new aviation design. The accelerated research process that is offered by Clean Sky represents an unprecedented opportunity for rapid progress in the introduction of green technology into aviation [1].

Clean Sky will demonstrate and validate the technology breakthroughs that are necessary to make major steps towards the environmental goals which are set by Advisory Council for Aeronautics Research in Europe (ACARE) which is the European Technology Platform for Aeronautics & Air Transport and to be reached in 2020:

- 50% reduction of CO₂ emissions through drastic reduction of fuel consumption;
- 80% reduction of NO_x (nitrogen oxide) emissions;
- 50% reduction of external noise;
- A green product life cycle: design, manufacturing, maintenance and disposal / recycling.

ACARE has identified the main contributors for achieving the above mentioned. The predicted contributions to the 50% of CO₂ emissions reduction target are:

- Efficient aircraft: 20-25%
 - Efficient engines: 15-20%
 - Improved air traffic management: 5-10%
- Clean Sky is made up of 6 ITD:
- SMART Fixed Wing Aircraft will deliver active wing technologies and new aircraft configuration for breakthrough and new products;
 - Green Regional Aircraft will carry low-weight aircraft using smart structures, as well as low external noise configurations and the integration of technology developed in other ITDs, such as engines, energy management and new system architectures;
 - Green Rotorcraft will develop innovative rotor blades and engine installation for noise reduction, lower airframe drag, integration of diesel engine technology and advanced electrical systems for elimination of noxious hydraulic fluids and fuel consumption reduction;
 - Sustainable and Green Engines will design and build five engine demonstrators to integrate technologies for low noise and lightweight low pressure systems, high efficiency, low NO_x and low weight cores and novel configurations such as open rotors and intercoolers;
 - Systems for Green Operations will focus on all-electrical aircraft equipment and systems architectures, thermal management, capabilities for “green” trajectories and mission, and also improved ground operations to give any aircraft the capability to in full exploit the benefits of Single European Sky;
 - Eco-Design will focus on green design and production, withdrawal, and recycling of aircraft, by the optimal use of raw materials and energies, thus improving the environmental impact of the whole products of life cycle and accelerating compliance with the reach directive [1].

Interrelation of aircraft forces at glide slope

Nowadays all approached schemes are calculated for glide slope angle which is equal to 3°. Instrument landing system provides the maintenance of established glide slope. But this angle cannot be considered like optimal according to the Clean Sky concept.

During the approach procedures the aircraft use the wing mechanization (flaps, slats) and landing gear release for the speed reduction. As a result, the aircraft aerodynamic characteristics decrease in two times in comparison to the “clean” wing.

Due to this factor pilots use up to 85% of maximum engines thrust while performing maneuvers.

These actions cause not only environment pollution but intensive noise level, great amount of fuel combustion and bigger separation norms by also turbulence during the approach. And according to above mentioned the Clean Sky concept has six directions by which this harmful influence can be reduced.

Our research has only one way by which the aircraft thrust during approach can be reduced. Our investigation shows that there is an inverse dependence between the angle of slope and aircraft thrust. If glide slope angle is greater less thrust is required during approach.

As it is known that mostly in all airports of Ukraine the glide slope angle is equal to 3° and sometimes to $2^\circ40'$. But there are some airports where glide slope angle is greater than the standard one. For example, such airports as Belbek airport, Kremenchuy airport, Severodonetsk and Kyiv airport "Antonov".

To understand the dependence between glide slope angle and the aircraft thrust let's consider the aircraft forces chart at the glide slope (fig.1).

The forces which act on the aircraft while it is performing the approach are represented by the set of equations:

$$\begin{cases} G \sin \alpha + P = X, & (1) \\ G \cos \alpha = Y, & (2) \end{cases}$$

where α is glide slope angle, G is aircraft weight, P is thrust, Y is lift force, X is drag force [2].

Another important element for this situation is coefficient of aerodynamic characteristics that represent the relation between lift force and drag force and is calculated by the formulae:

$$K = \frac{Y}{X}, \quad (3)$$

where K is coefficient of aerodynamic characteristics.

Generally this coefficient is equal to 6 or 7 [2].

Calculation of the aircraft thrust dependence from glide slope angle

Let's now consider how aircraft thrust decreases with increase of the glide slope angle. By using formulae (1), (2) and (3) let's make the correspondent calculations for the aircraft weight of which is equal to 100 tones.

For the aircraft where the glide slope angle is equal 3° the calculations are make in such a way:

$$Y = G \cos \alpha = 100 \cos 3 = 99.8 \text{ t},$$

$$X = \frac{Y}{K} = \frac{99.8}{6} = 16.64 \text{ t},$$

$$P = X - G \sin \alpha = 16.64 - 5.2 = 11.44 \text{ t}.$$

For the aircraft where the glide slope angle is equal to 4° the results slightly differ from the previous one:

$$Y = G \cos \alpha = 100 \cos 4 = 99.75 \text{ t},$$

$$X = \frac{Y}{K} = \frac{99.75}{6} = 16.63 \text{ t},$$

$$P = X - G \sin \alpha = 16.63 - 6.97 = 9.66 \text{ t}.$$

For the aircraft where the glide slope angle is equal to 5° the calculations are make like these ones:

$$Y = G \cos \alpha = 100 \cos 5 = 99.6 \text{ t},$$

$$X = \frac{Y}{K} = \frac{99.6}{6} = 16.6 \text{ t},$$

$$P = X - G \sin 5 = 16.6 - 8.7 = 7.9 \text{ t}.$$

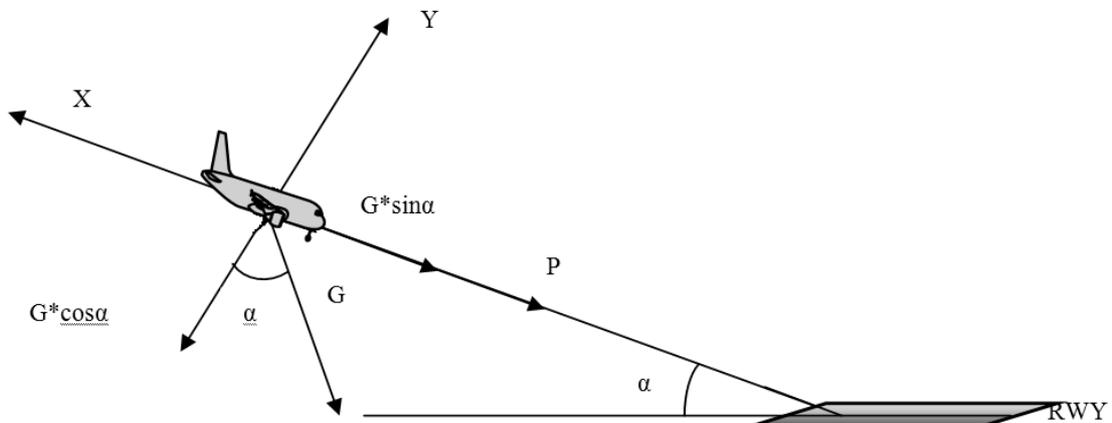


Fig. 1. Aircraft forces chart at glide slope (RWY is runway)

For the aircraft glide where the slope angle equal to 6° the calculations are make in such a way:

$$Y = G \cos \alpha = 100 \cos 6 = 99.4 \text{ t,}$$

$$X = \frac{Y}{K} = \frac{99.4}{6} = 16.57 \text{ t,}$$

$$P = X - G \sin 6 = 16.57 - 10.45 = 6.12 \text{ t.}$$

The made calculations show that the greater is glide slope angle the less is value of thrust. Such inverse dependence may be shown by the graph (fig. 2, a).

Let's also make the same calculations but for heavy aircraft with weight of 210 t. And coefficient of aircraft aerodynamic characteristics will be equal to 7.

For the aircraft where the glide slope angle is equal to 3° the calculations are:

$$Y = G \cos \alpha = 210 \cos 3 = 209.71 \text{ t,}$$

$$X = \frac{Y}{K} = \frac{209.71}{7} = 29.96 \text{ t,}$$

$$P = X - G \sin 3 = 29.96 - 11.0 = 18.96 \text{ t.}$$

For the aircraft where the glide slope angle is equal to 4° the results will be:

$$Y = G \cos \alpha = 210 \cos 4 = 209.48 \text{ t,}$$

$$X = \frac{Y}{K} = \frac{209.48}{7} = 29.92 \text{ t,}$$

$$P = X - G \sin 4 = 29.92 - 14.65 = 15.27 \text{ t.}$$

For the aircraft where the glide slope angle is equal to 5° the calculations are:

$$Y = G \cos \alpha = 210 \cos 5 = 209.2 \text{ t,}$$

$$X = \frac{Y}{K} = \frac{209.2}{7} = 29.89 \text{ t,}$$

$$P = X - G \sin 5 = 29.89 - 18.3 = 11.59 \text{ t.}$$

For the aircraft where the glide slope angle is equal to 6° the results will be better than in previous case:

$$Y = G \cos \alpha = 210 \cos 6 = 208.84 \text{ t,}$$

$$X = \frac{Y}{K} = \frac{208.84}{7} = 29.83 \text{ t,}$$

$$P = X - G \sin 6 = 29.83 - 21.95 = 7.88 \text{ t.}$$

As the aircraft for which the calculations were done are heavy the values of thrust are greater but there is also the inverse dependence between glide slope angle and thrust. The graph of this dependence is shown in figure below (fig. 2, b).

Advantages and disadvantages of the change of glide slope angle

According to the results of these calculations the increase of glide slope angle causes the decrease in the required engine thrust. And that is one of the main tasks of Clean Sky concept.

If lower thrust is required then engines will not provide the same noise level during approach.

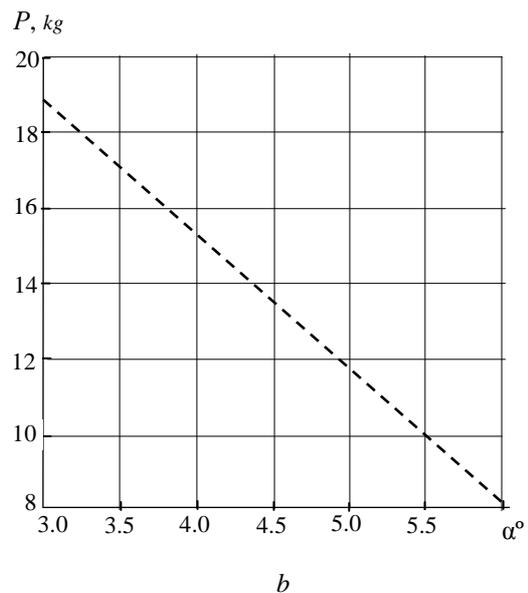
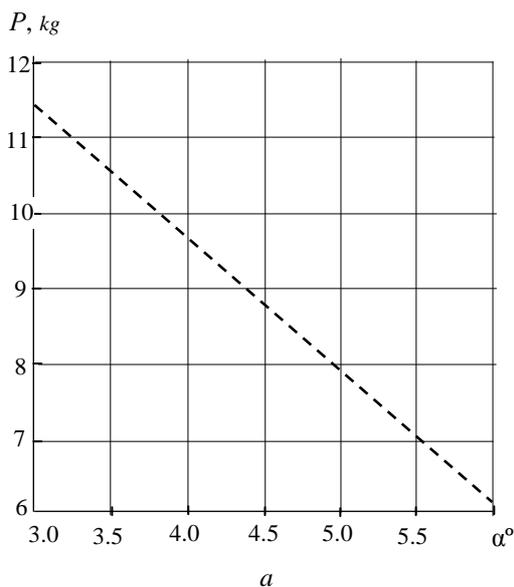


Fig. 2. Thrust P dependence on the glide slope angle α :
 a – for $G=100$ t and $K=6$;
 b – for $G=210$ t and $K=7$

This is very important for the airports that are situated near cities or towns. Correspondingly this fact is valued from the point of view of environmental pollution. The harmful effect will be considerably less.

Another advantage of thrust decrease is representation from efficient and economical point of view. The lower thrust is required the less amount of fuel is needed.

The amount of thrust also influences on the intensity of aircraft turbulent wake. Correspondingly the separation minima can be reconsidered and decreased. It will create an opportunity for increasing of air traffic volume.

The greater glide slope angle is important and necessary in case of engine failure. That means a pilot will have more time on the decision making.

But despite great amount of advantages some disadvantages may be pointed out. First of all the change of glide slope angle will require the change of all approach schemes. That will take a lot of time and resources.

Another fact is that attention must be paid to the training system of flight crew as there are a lot of difficulties while performing approach with greater glide slope angle. It is difficult to maintain the speed during approach especially in case of reducing of approach speed. And the pilotage must be performed more accurately.

So, in order to receive all the possible advantages while increasing the glide slope angle the sufficient training and preparatory system must be established especially for pilots.

Conclusions

The change of glide slope profile can be one of the best and the quickest methods of solution of the main tasks of European Clean Sky concept. The change of glide slope profile positively influences on engine operation mode because the less thrust is required. The less thrust is required the less fuel is required, the less is noise and the less is harmful influence on the surrounding environment.

Such approach trajectory helps to meet all the requirements of Clean Sky concept the main task of which is reduce harmful influence of modernizing aviation technology.

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