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INFLUENCE OF POWER UNIT CONFIGURATION LAYOUT OF A REGIONAL JET ON PERFORMANCE AND DIRECT OPERATING COST

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Abstract

The motivation for this research work comes from the HELENA project and the later initiative of 4 central European countries devoted to the creation of modern European Regional Aircraft. The paper presents a configuration of a significantly lower noise, emission, top-class operational economy, highly increased safety level, extra ordinary cabin comfort and reduced boarding time. Aircraft is powered by one external engine, selected for cruise conditions and supplemented by another internally located engine, used mainly for take-off and emergency. Both engines are located in the rear part of aircraft, in its plane of symmetry which is beneficial when one of the engines is non-operational. Every engine can maintain a steady level flight and safe landing if the other unit fails. The reason for big improvement of flight economy, numerically proved in this paper, did not come from aerodynamic drag reduction, but mainly from much better performance of the selected cruising engines. Larger turbofans are usually more fuel efficient because of more advanced technologies used and the characteristics of the phenomena occurring inside the engines. Specific fuel consumption for turbofans used in research variants of the airplane is respectively 19.65 % and 31.12 % lower than for CF-34-8E, which is very similar to final profits. The most likely percent of fuel consumption reduction that can be achieved is between these two values received from performed calculations.

1 Introduction

This paper was triggered out by an initiative proposed by Prof. J. Szodruch of DLR in the HELENA project [1] in 2008. Among the main goals of this initiative was the transfer of research excellence into a world class product. In order to achieve this goal, a number of actions were planned including (1) keeping Aeronautics and Air Transport Research on political agenda for maintaining Europe's competitive position; (2) concentrating the ACARE activity on pre-competitive research; (3) providing the European Commission with attractive political, technical, economical pilot-project in Aeronautics/Air Transport; (4) bridging the gap between excellent research and ecological/economical world class product; (5) integrating (mainly) new member states and countries with lower aeronautical profile, decreasing their dependency on the value chain of established OEM's (*Original Equipment Manufacturer) and (6)* strengthening the position in the regional aircraft market in Europe (vs. Japan, Brazil, Canada, Russia, China and India). The project proposal was then advanced by an international team of designers and researcher from DLR (Germany), ILOT (Poland), VZLU (Czech Republic) and INCAS (Romania). Under the umbrella of this initiative, the Polish group of designers representing ILOT and PW have developed a conceptual design of turbo-fan aircraft endowed with 2 engines (1 main, external for cruise and landing) and one internal (auxiliary, for take-off and emergency if necessary).

The subject of this paper is the estimation of potential benefits associated with the use of innovative configuration of regional class passenger aircraft, equipped with one cruising engine and one auxiliary. The auxiliary engine, located inside the fuselage and used only in the emergency situations and in flight near the ground, remains off during high altitude flight in order to reduce fuel consumption. In addition, the research configuration is equipped with a V-type tail. The study focused on assessing the benefits only from power unit layout change and adding V-type tail configuration. Other innovations specific to the HELENA [1] project, further progressed by PW-ILOT team (forward swept wing, Canard wing, etc.) [2,3] were neglected in this paper in order to focus on potential benefits expected from the replacement of 2 engine configuration into configuration with 1 main engine for cruise and landing, and one auxiliary engine for take-off and emergency only (shut-down during cruise). The geometry of Embraer E-175 LR airplane was chosen as initial geometry for further modifications. Comparison of the fuel consumption, range and flight endurance between classical configuration and the single external engine configurations presented in this paper is based on the numerical simulation performed by A. Sieradzki [4]. These results might be further used for the assessment of the European requirements related to the strengthening of Air Transport System, both the smaller one provided by SAT [5] and by its greater segment provided by commuters.

2 Regional jet market tendencies

Regional jet market shows very good potential for development (Fig 1), especially in the segment of jet airplanes that could carry from 80 to 120 passengers, with range above 3000 km. Many economic factors are responsible for that, e.g. fuel prices growth, air connection network characteristics or scope clauses relaxation in the USA. The continuous development of technology is also very important, because it allows for the use of high-end technical solutions, known from large wide-body airliners, in small regional jets. This opens up new profitable markets for airliners manufacturers and allows meeting the needs of new carriers. [6-7].

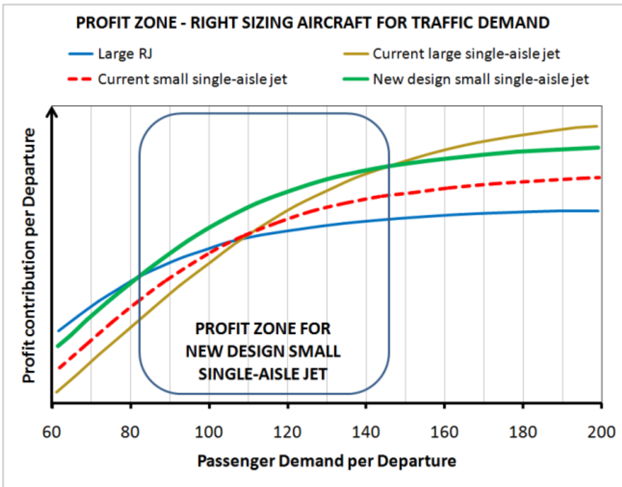

Fig 1 Technology development created a new profitable market for airlines and airplanes manufacturers [8]

From the point of view of the airline companies, the most important factor is the maximum profit, which results from the low operating costs. Using the newest jet engines, which guarantee the lowest fuel consumption, noise emission and pollutants emission, is necessary to achieve this goal. The biggest jet engines manufacturers, Pratt & Whitney and General Electric, are working on solutions for regional jet markets. GE is trying to develop classical turbofan engine, focusing on increasing the internal efficiency of the engine (Leap-X engines family), but P&W probably have the lead because of its new family of jet engines called Pure Power. Newly designed geared turbofan engines (similar were used on BAe 146), with very high Bypass Ratio (BPR) and significantly improved propulsive efficiency, are the chance for P&W to control the market. Both manufacturers promise similar fuel consumption and pollutants emission, but P&W engine will be probably quieter (due to lower rotational speeds) and 10-20% cheaper in maintenance costs (due to lower temperatures inside the core of the engine). It will have simpler construction and lower mass. Also, the response of the engine to thrust lever motion will be quicker than in GE LEAP-X due to smaller moments of inertia. However, it has to be mentioned that the reliability of such large geared turbofans which P&W is going to produce (BPR ≈ 12) is not known. Also, the aerodynamic drag increase connected with using larger nacelles for P&W engines will reduce its advantage. Taking this all into consideration, it is hard to clearly state that P&W took better strategy to develop its jet engines [9-10].

3 Flight conditions

In this phase of the work, the computational flight conditions were determined on the basis of the Embraer E-175 LR specification and the International Standard Atmosphere (ISA) model. They are similar to cruise conditions for current airliners. The altitude of 10 000 m and flight speed of 0.7 Ma was assumed. Actually, the airliners achieve higher airspeeds during cruise, but due to the intensification of wave phenomena, the decision was made to perform the calculations for slightly lower Mach number. Moreover, the assumed flight speed represents, to a certain extent, also the other (slower) phases of flight, such as climbing or descend, which in case of short regional flights take relatively high amount of time.

The average mass of the Embraer E-175 LR during cruise was calculated with use of relationships described in [11] and the assumption of 6% fuel reserve during landing, and equals m_{av} = *33721 kg*. The average lift coefficient was received from the below equation:

$$C_L = \frac{2 m_{av} g}{\rho V_\infty^2 S} = \frac{2*33721*9{,}81}{0{,}413*209{,}7^2*72{,}9} = 0{,}5 \quad (1)$$

where: m_{av} - average mass of aircraft; g - acceleration due to gravity; ρ - air density; V_∞ - airspeed; S - wing reference area.

4 Initial configuration

The main part of the work began with the creation of initial configuration geometry based on the very popular Embraer E-175 LR. Its geometry was reconstructed from the available pictures and sketches. The wing and tail airfoils were chosen from NASA and NACA airfoils family respectively, on the basis of NASA guidelines [12] and experimental data [13]. For the wing section, the supercritical NASA SC(2)-0714 was chosen. It was designed to minimize the wave drag associated with local supersonic flow above top surface of the airfoil. The thickness of NASA SC(2)-0714 is 14% (similar value measured in E-175 LR sketches) and design lift coefficient is 0.7. For V-tail section NACA0012 airfoil was used, due to the fact that the thickness of the horizontal/vertical stabilizers measured in the E-175 LR sketches varied from 11 to 12%. The same airfoil (NACA0012) was also used in the winglets geometry. Due to the presence of the V-tail configuration and the inboard engine in the research variant of the airplane, the aft section of the fuselage of Embraer E-175 LR had to be modified (Fig 2). The fuselage was redesigned to be more spacious, and therefore to be able to contain an auxiliary engine inside. The areas and angles of the V-tail were derived on the basis of the guidelines specified in [14]. The incidence angle of stabilizers was set later in the iterative way, to ensure balance conditions for the assumed center of gravity position. The complete initial geometry is presented in Fig 3.

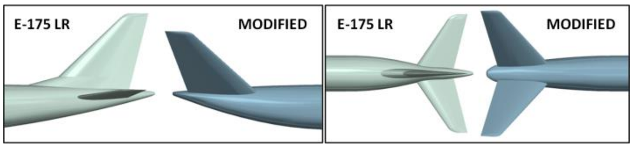

Fig 2 Tail geometry comparison (left - side view, right - top view)

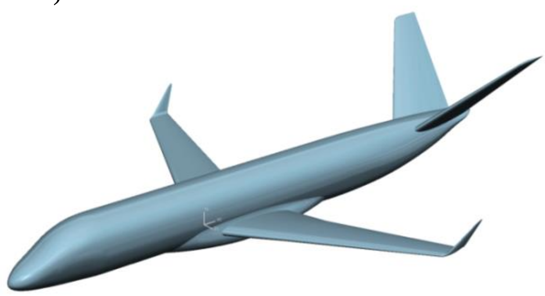

Fig 3 Complete initial geometry (airframe without engines)

5 CFD analysis and its verification

All calculations were carried out in a well-known, Finite Volume Method based, CFD software – ANSYS Fluent. In this part of the work, the aerodynamic characteristics of isolated wing and tail airfoils, as well as complete wing and complete initial airplane, were calculated. From the viewpoint of the further analysis, the most important were the calculations of the complete airplane, but at this stage, some simpler configurations were also examined. This allowed verifying the CFD results accuracy, on the basis of experimental data of applied wing airfoil [13], and the analytically derived complete wing characteristics (based on half-empirical relationships described in [15]).

All cases were analyzed with the same solver settings. Double Precision, Density Based Solver with ideal gas model and Spalart-Allmaras turbulence model were used. The energy equation was also taken into account in calculations.

All meshes were created in ANSYS Meshing software and consist mainly of TRI (2D) or TETRA (3D) elements (Fig 4). Far away from walls, the meshes were of unstructured type, because of a high complexity of modeled geometry and a shorter creation time. Near the walls they changed into structured layers of QUADS/PRISM elements, to properly model the flow in the boundary layer regions. These elements provide needed y+ value for Spalart-Allmaras turbulence model (y+ < 5 or 30 < y+ < 300). For 2D airfoil cases fine (y+ < 5) and coarse (30 < y+ < 300) meshes were created. This offered the possibility to check the influence of the mesh density on the flow equations solution in the boundary layers and the final results at the end. 3D cases were analyzed only with the coarse grids (30 < y+ < 300), because of high number of elements in these cases. The external boundary of the domain was modeled with Pressure Farfield boundary condition type, and the surface of the models with Wall condition. For 3D cases, Symmetry condition was also used (only half-models were analyzed to save computing time). The radius of the domains for airfoils calculations was 20 chord lengths and for 3D cases it was 300 m (90 chord lengths or 11.5 wingspan or 10 fuselage lengths).

The last stage of this part of the work was the calculation of aerodynamic characteristics of the complete initial geometry of the airplane. It was assumed that the center of gravity is located in 27% MAC, and about this point the pitching moment was reduced to zero by deflecting the V-tail stabilizers. During this process, the aim was to maintain the total CL value of 0.5 and it was an iterative procedure. Finally, the incidence angle of V-tail stabilizers was set to -2.5 degrees, which guarantees horizontal flight with the angle of attack 4 degrees and CL=0.513 (CG at 27.1% MAC).

Additionally, the values of aerodynamic drag of the complete airplane were corrected by taking into account a drag increase connected with the used production technology and the presence of gaps between stabilizers and steers etc. It was calculated on the basis of the guidelines described in ESDU [16].

As it can be seen in Fig 6, the CFD calculations (Fig 5) results show relatively good agreement, especially for the complete 3D wing analysis. For the 2D airfoil results, there is a greater discrepancy from the experiment data, but similar for both, coarse and fine meshes. This means that the coarse mesh (30<y+<300) is probably good enough for these cases.

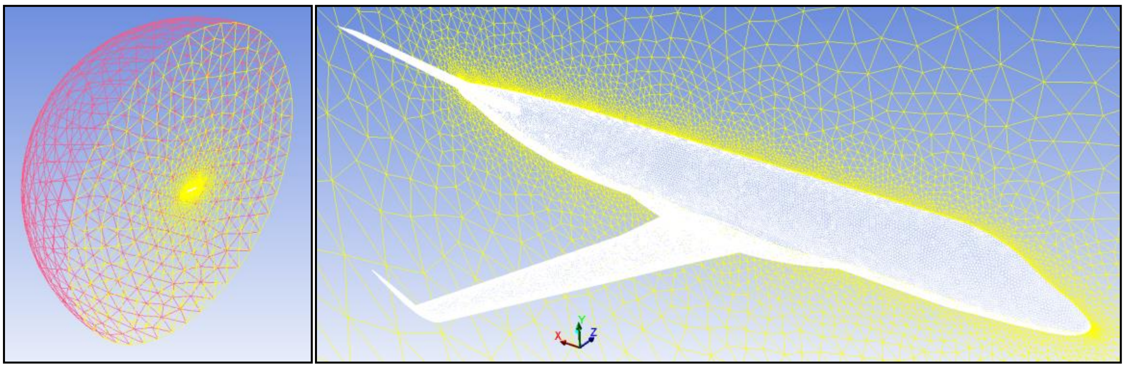

Fig 4 An example: semispherical calculation domain for 3D case (left) and mesh density around the centrally located airplane (right)

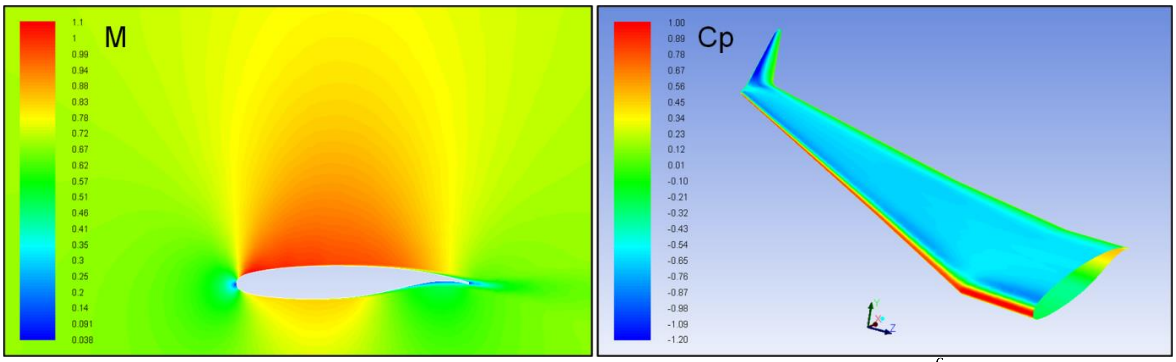

Fig 5 Contours of Mach number for NASA SC(2)-0714 airfoil (2D case, M=0.7, Re=15x10^6, CL=0.634) and pressure coefficient for complete wing (M=0.7, CL=0.492)

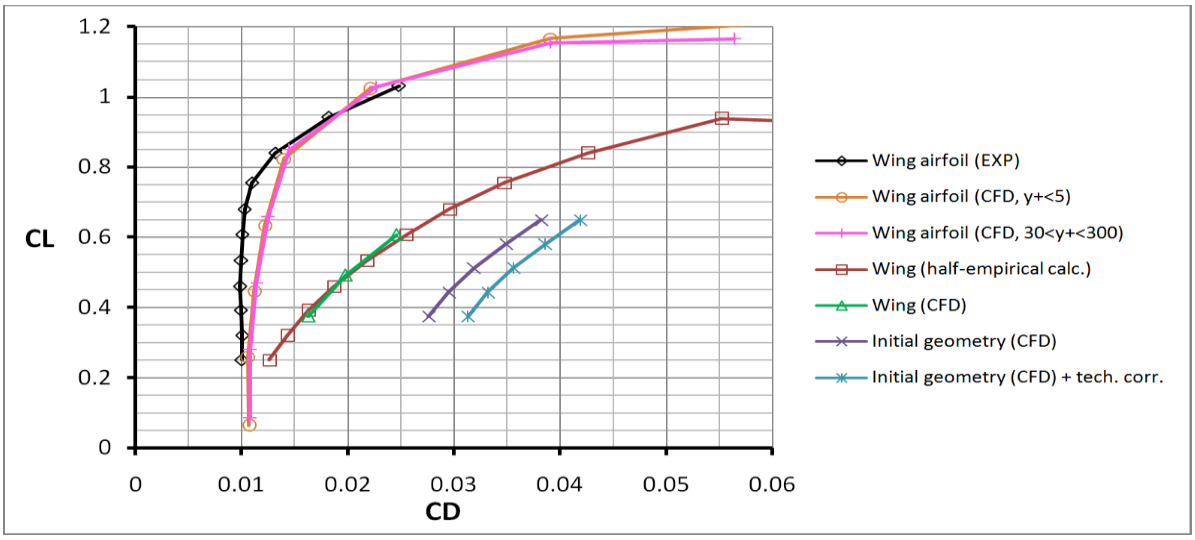

Fig 6 CFD results for wing airfoil (NASA SC(2)-0714), isolated wing and complete initial airplane, compared with experimental results for wing airfoil and half-empirical calculations for isolated wing

6 Power unit analysis

This part of the paper deals with turbine engines. On the basis of the pre-determined aerodynamic characteristics for the complete initial configuration, the appropriate power plant for each of the three test configurations was chosen (baseline and two variants of research). For this purpose, a lot of specification data (for 49 engines) concerning turbofan engines currently used and being under development (thrust from 25 kN to 262 kN) was gathered [17, Pratt& Whitney, General Electric]. The analysis was deliberately extended to some more powerful engines than needed to make fuller statistics and catch some relationships between the engines specification data used in further calculations.

First of all, the power unit thrust requirements for baseline airplane and two variants of research were designated. The work focused on a proper selection of cruising engine for research configurations and two engines for baseline airplane (mounted in pylons below wing). In case of research configuration, the cruise is the phase of flight which decides on how large will be the cruising engine. While in baseline airplane, the critical phase of flight can be also take-off, and it was taken into consideration as well. The statistics about thrust loading were used to calculate total thrust needed for take-off. For typical regional aircraft thrust loading during take-off is about 0.33 and needed thrust could be designated as:

$$\frac{T_{T0}}{g*MTOW}=0,33 \rightarrow T_{T0}=0,33*9,81*38790=125kN \quad (2)$$

where: T_{T0} – initial take-off thrust, g - acceleration due to gravity, $MTOW$ - Maximum Take-Off Weight.

While in cruise, the needed thrust was calculated on the basis of vertical speed requirement at practical ceiling:

$$T_{CRUISE} = m_0 \left(\frac{C_D}{C_L} + \sin\gamma \right) \Big/ \left(1 - T_{LOSS}\right) \qquad (3)$$

where $\gamma = ROC/V$ – angle of climb; *ROC* – rate of climb (typically 300 ft/min); $V = 0.7\ Ma = 41278\ ft/min$ - speed of flight ($H=10000$ m conditions); $m_0 = 36498\,kg$ – airplane mass at the beginning of cruise and $T_{LOSS} = 4\ \%$ – thrust loss resulting from engine mount [18].

Finally, after the substitution of the required data, the needed thrust value during cruise was 27.5 kN.

The aim of the second stage of this part of the work was to select proper engines for baseline configuration (two currently produced engines in nacelles below wing) and two variants of research. The first variant of research uses as cruising engine the currently produced and exploited engine and the second one uses the newest power unit, which is in the phase of research and development. The characteristics of the engine for the first variant are known, while for the second can be only predicted on the basis of the manufacturer promises. Therefore, they must be subject to caution. The results for the first variant could be interpreted as the low limit, and for the second one as the high limit of potential benefits associated with the use of presented configuration of an airplane.

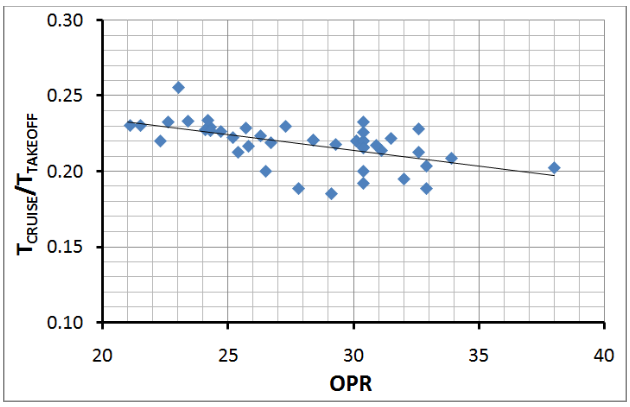

Fig 7 Value of $T_{CRUISE}/T_{TAKEOFF}$ ratio in a function of Overall Pressure Ratio (OPR) for chosen jet engines

It was relatively easy to check the first requirement concerning take-off thrust, because all engines manufacturers present take-off thrust at sea level at their specification tables. In turn, cruise thrust is often neglected and in some cases had to be estimated on the basis of Overall Pressure Ratio of the engine and the statistics presented in Fig 7.

Most engine manufactures provide cruising thrust and specific fuel consumption (*SFC*) value at 35 000 feet and flight speed 0.8-0.82 Ma. Assumed flight conditions are a bit different (*M=0.7*), and some corrections had to be implemented. Basing on the example turbofan engines characteristics [14], it was assumed that thrust value is the same for both, flight speeds and SFC changes linearly (as shown in Fig 8).

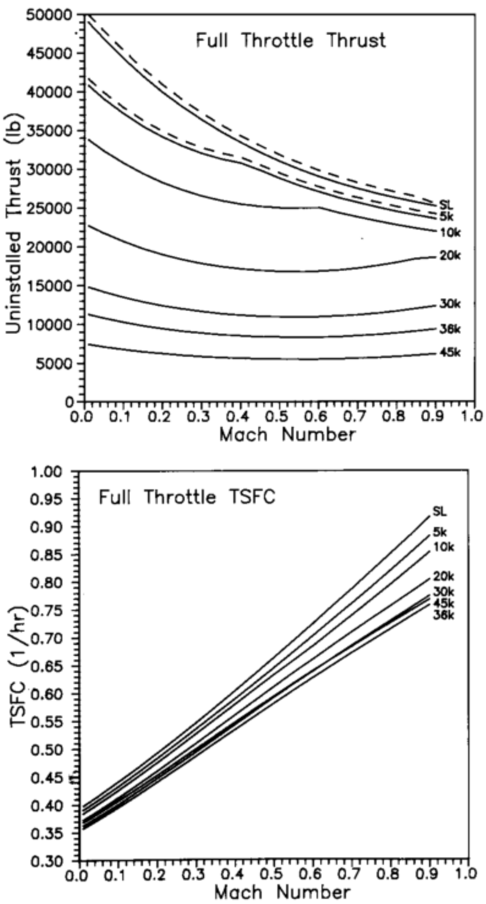

Fig 8 Changes in performance (uninstalled thrust and specific fuel consumption) for typical turbofan engine, [14]

In this way, the characteristics of the engines, taken into account in subsequent calculations were estimated. For the baseline airplane configuration, two CF-34-8E engines were chosen. They fulfill all requirements and confirm the validity of conducted calculations - this type of engine is currently mounted on the Embraer E-175 LR. For the first variant of the research, the well-known CFM56-5C2 was selected as one cruising engine. It has slightly more thrust than both CF-34-8E in baseline configuration. The second variant of research received new geared turbofan PW1133G from Pratt & Whitney Company, and its performance was estimated basing on manufacturers promises and gathered statistics. All data were collected in Tab.1.

Engine:	**CF-34-8E**	**CFM56-5C2**	**PW1133G**
Fan diameter [*m*]	1.36	1.84	2.06
Bypass Ratio (BPR)	5	6.6	12
Overall Pressure Ratio (OPR)	28.5	31.5	> 40*
$T_{TAKEOFF}$ [*kN*]	64.5	138.8	142.8
$SFC_{TAKEOFF}$ [*g/(kN*s)*]	10.91	9.06	7.70
T_{CRUISE} (0.7-0.8 M) [*kN*]	14.2	30.8	28.6
$SFC_{CRUISE\ M=0.8}$ [*g/(kN*s)*]	19.26	15.44	13.24
$SFC_{CRUISE\ M=0.7}$ [*g/(kN*s)*]	18.22	14.64	12.55

Tab 1 Engines chosen for three calculation configurations (* - expected unconfirmed value)

7 Complete airplanes calculation models

In this part of the work, the complete geometry of all three airplane calculation models was created. A considerable amount of time was spent on the engines integration process. First of all, the short duct nacelles were designed based on the NACA-1 guidelines [19], with the same design parameters for all configurations. This way, the flow through nacelles was similar and they have similar value of drag coefficient. The engines were not modeled, but the Mass Flow Ratio ($MFR = \dot{m}/\rho A_{hl} V_{\infty}$, where $\dot{m}$ is the mass flow through engine and A_{hl} is the area of inlet surface) was checked for all designed nacelles to make sure that they work at the same inlet conditions. During normal cruise conditions, the MFR value varies from 0.7 to 0.8. Isolated nacelles were CFD tested to check if they fulfill all requirements (the CFD results of final isolated nacelles in Tab2).

Engine	CF-34-8E	CFM56-5C2	PW1133G
$CD_{NACELLE}$	0.0283	0.0269	0.0265
$\dot{m}$ [*kg/s*]	85.6	157.1	196.9
MFR	0.754	0.756	0.756

Tab 2 CFD results of isolated engines nacelles

Then, the created nacelles were precisely placed in relation to the other parts of the airframe, including proper pitch and yaw angles. The guidelines from literature [14] and measured flow directions were used to fix the nacelles at the right place and angle. All efforts were made to ensure that the axis of symmetry of each nacelle coincides with the local flow direction. This was very important, because it guarantees the lowest drag and the most homogeneous flow field at inlet.

In the next stage, some modifications of the geometry of two variants of research were made to ensure similar longitudinal stability as in the baseline configuration. Taking both engines from under the wing to the tail of the airplane moved the airplane center of gravity to the aft. Taking into account the masses of the engines, the CG travel distance was estimated (≈ 0.9 m) and the whole wing was translated by this value. This way, all the configurations under consideration (Fig 9) have similar CG location with respect to the Mean Aerodynamic Chord. The described procedure resulted in two variants of research having approx. 6.5% lower tail volume coefficients than the baseline airplane (due to shorter tail arm), but still at least 13.8 % higher than typically in this type of aircraft.

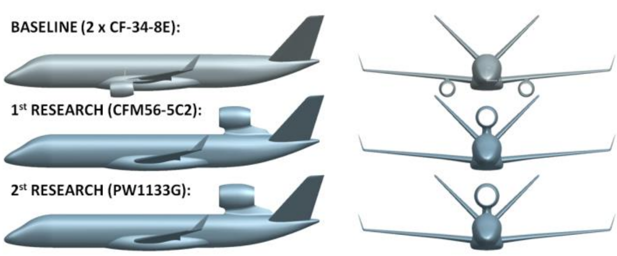

Fig 9 Three complete airplanes calculation models (baseline and two variants of research)

Finally, the influence of the engines thrust on pitching moment and balance conditions was estimated. For the baseline configuration, the thrust of both engines, located below the center of gravity of the airplane, generates positive pitching moment value. On the other hand, the research configuration (in both variants) has the cruising engine located far above the center of gravity of the airplane. Therefore, the pitching moment value generated by the thrust of such engine will be certainly negative. The approximate needed thrust to maintain flight level at cruise conditions is 25 kN (calculated from (3) with assumption of ROC=0). For this value, the pitching moment coefficient associated with engines thrust was calculated. The results were collected in Tab 3.

Location of the engine (engines)	Z_{CG} *[m]*	*M [kN*m]*	*Cm*
Under the wing	- 1.8	45	0.0206
In the tail section	3.3	- 82.5	- 0.0377

Tab 3 Pitching moment coefficient values associated with engines thrust

8 CFD results

CFD analysis (Fig. 10) was performed for all three calculation models, with the use of the same settings and assumptions as mentioned before (in "*CFD analysis and its verification*" section). All efforts were made to ensure that each configuration was analyzed with the same lift coefficient (CL=0.5). Due to differences in geometries, it was needed to specify a different angle of attack for each of them. This was done in an iterative way, basing on $dC_L/d\alpha$ derivative calculated for initial configuration. The final angles of attack and the aerodynamic coefficients for all three calculation models were presented in Tab 4. Given *CD* value is the CD_{CFD} value corrected for used production technology and the presence of gaps between stabilizers and steers. The *Cm* values in Tab almost exactly correspond to the previously designated values of thrust-induced *Cm* for selected airplane configuration, but with opposite sign. It should be noted that in both variants of research there was a need to change the incidence angles of V-tail stabilizers. In the initial and baseline configuration this angle was equal to -2.5 degrees. For research variants it was changed to -3 degrees. This value allowed achieving the balance conditions with only slightly different CG position (max. 2.5 % MAC difference between three tested configurations was achieved).

9 Costs analysis

The last part of the work describes the costs analysis, which verified the expectations and provided quantitative information on the expected savings. Based on current fuel prices, economic benefits were estimated in terms of one flight and one year of operation of the aircraft. First of all, the most important data for all tested configurations were gathered in Tab 5, and on their basis, the fuel consumption, range and flight endurance were estimated.

Configuration	α [°]	CL	CD_{CFD}	CD	ΔCD [%]	$\bar{x}_{CG}$ [%]	Cm
2 x CF-34-8E	3.948	0.4999	0.03366	0.03733	BASE	23.7	-0.0206
1 x CFM56-5C2	4.085	0.5000	0.03397	0.03763	+ 0.8 %	24.6	0.0383
1 x PW1133G	4.088	0.4999	0.03437	0.03803	+ 1.88 %	26.2	0.0381

Tab 4 CFD results for *CL=0.5* and all calculation models

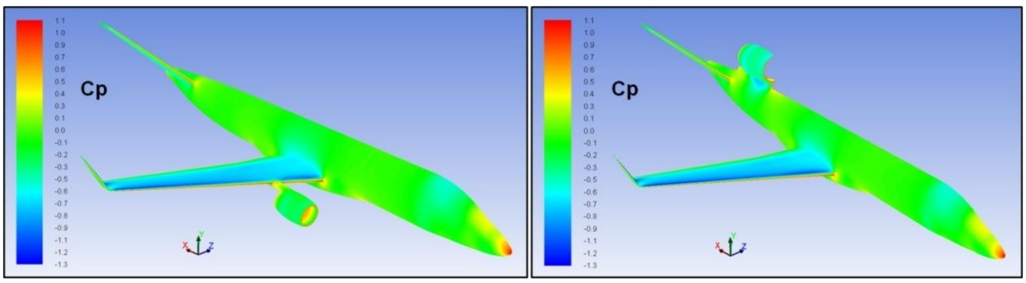

Fig 10 Pressure coefficient values on the surface of the airplanes, for baseline configuration (2 x CF-34-8E - left) and second variant of research (1 x PW1133G - right)

The calculations took into account the fuel consumption associated with providing the required thrust and also the need to power the air conditioning system and generators. On the basis of [11], it was possible to calculate the equivalent thrust value needed to power additional systems and to designate the total specific fuel consumption. This is the reason why T_{CRUISE} value is slightly higher than drag force (F_D) value for each configuration.

Configuration	**2 x CF-34-8E**	**1 x CFM56-5C2**	**1 x PW1133G**
CD	0.03733	0.03763	0.03803
$F_D\ [kN]$	24.71	24.91	25.17
ΔF_D [%]	BASE	+ 0.8 %	+ 1.88 %
$T_{CRUISE}\ [kN]$	25.74	25.95	26.22
$(T_{CRUISE})_{max}\ [kN]$	28.38 (2 x 14.19)	30.8	28.56
$T_{CRUISE}/(T_{CRUISE})_{max}$ [%]	90.7 %	84.2 %	91.8 %
Fuel consumption			
$SFC\ [g/(kN \cdot s)]$	18.22	14.64	12.55
$FC\ [kg/h]$	1688	1367	1185
$FC\ [kg/km]$	2.24	1.81	1.57
$\Delta \boldsymbol{FC}$ [%]	**BASE**	**- 19 %**	**- 29.83 %**
Range and flight endurance (5% fuel reserve during landing)			
$\sim(t_{max})_{\max\ fuel}\ [h]$	5.25	6.49	7.49
$\sim(R_{max})_{\max\ fuel}\ [km]$	3965	4896	5651
$\sim(t_{max})_{\max\ payload}\ [h]$	3.92	4.84	5.59
$\sim(R_{max})_{\max\ payload}\ [km]$	2962	3656	4220

Tab 5 CFD and power unit analysis summary (range and flight endurance given for max. fuel quantity and max. payload)

Configuration	**Fuel price [$]**	**Δ [$]**
Per 1 flight (3.6 h):		
2 x CF-34-8E	2 303	BASE
1 x CFM56-5C2	1 866	- 438
1 x PW1133G	1 616	- 687
Per 1 year of operation (3940 h):		
2 x CF-34-8E	2 522 316	BASE
1 x CFM56-5C2	2 043 000	- 479 316
1 x PW1133G	1 769 959	- 752 357

Tab 6 Possible economic benefits associated with use of presented research airplane configuration

10 Conclusions

Potential benefits connected with the exploitation of the research variants of the airplane were presented in Tab 6. The received values are worth special attention. In this paper, two variants of research configuration were tested - the first one equipped with the well-known CFM56-5C2 engine and the second with the new geared turbofan PW1133G. According to calculations performed, they have respectively 19% and 29.8% reduction in fuel consumption in comparison to baseline aircraft with two CF-34-8E engines under the wing. These values are directly reflected in the calculated financial profits.

The reason for such big improvement of flight economy certainly did not come from the aerodynamic drag reduction, which for research variants is even slightly higher than for the baseline airplane. It results mainly from much better performance of the selected cruising engines. Larger turbofans are usually more fuel efficient, because of more advanced technologies used and the characteristics of the phenomena occurring inside the engines. Specific fuel consumption for engines used in research variants of the airplane is respectively 19.65 % and 31.12 % lower than for CF-34-8E, which is very similar to final profits. This is the main reason behind the calculated financial savings.

It is also worth to mention that the most likely percent of fuel consumption reduction which can be achieved is somewhere between two values received from the calculations.

Probably, it would be lower than 29.8%, because the performance of PW1133G was only estimated on the basis of the manufacturers promises, and higher than 19% because, nowadays, it is very rare to design new airliner with the use of existing engines. Usually, they are designed in parallel with the use of the most recent technologies available.

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