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Configuration of the Medium-Haul Twin-Fuselage Passenger Aircraft

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Abstract

This paper shows the unique characteristics and disadvantages of an aircraft of the classical single-fuselage scheme. It provides an overview of the aircraft built according to the twin-fuselage configuration. The brief description of Airbus 320 series and Boeing 737 series is given in this paper, as well as their inflight performance. The article shows the distinctive characteristics of the single-fuselage and twin-fuselage schemes of the aircraft. The variant and the rationale for benefits of the configuration of the medium-haul passenger aircraft of the twin-fuselage scheme are considered, taking into account the specifications and passenger capacity. We also consider the rationale for the level of security in the version of the twin-fuselage scheme and compare it with the single-fuselage one. As the prototype of the proposed scheme we have chosen Airbus 320 medium-haul and narrow-body aircraft. The practical implementation of the proposed layout will ensure a top flight safety and increase the passenger capacity. At the same time, it will meet the needs of the carrier.

Keywords: configuration, twin-fuselage aircraft, passenger capacity, yaw.

INTRODUCTION

A modern medium-haul passenger aircraft is the single-fuselage and cantilever monoplane with:

- a pressure cockpit allowing the placement of six chairs in a row with one pass (Table 1);
- a moderately swept wing of powerful high-lift system, geometric and aerodynamic twist;
- a wing loading and a wing aspect ratio. It gives the possibility to get the maximum aerodynamic efficiency at the minimum weight of the wing;
- a single-fin empennage. It provides transverse stability and controllability in all flight modes including flight with asymmetric power;
- a power plant. It is located under the wing and contributes to its unloading and trimming;
- an even number of engines equipped with a reverse of high bypass ratio, with minimal fuel flow rate, specific fuel consumption and low noise level;
- tricycle landing gears with high-pressure tires allowing the aircraft operation on the hard-surface runways;
- a minimum structural weight fraction. It is achieved by means of rational layout, implementation of innovative ideas, advanced technologies and modern materials.

The listed features, in addition to their economic efficiency, have a direct connection with the aircraft flight operation and accidents prevention.

Typical types of this configuration are Boeing 737-700 and Airbus A320 aircraft (Figure 1) [1-2, 6].

Table1. Comparison of airplanes' features: Boeing 737-700 vs Airbus A320

	Unit	Boeing 737-700	Airbus A320
Number of passenger seats		146	150
The number of seats in a row		6	6
Gross weight	*kg*	70,000	75,500

Wing area	m^2	125	122.5
Wing sweep	*angle degree*	25	28
Wing loading	kg/m^2	560	616
Wingspan	*m*	34.3	34.1
Wing aspect ratio		9.4	9.5
Aerodynamic efficiency		14.8	15
Number of engines		2	2
Bypass ratio		6	6
Fuel flow rate	*kg/h*	2,600	2,700
Location of engines		under the wing	under the wing
Takeoff noise level	*dB*	82	82
Empty weight	*kg*	38,140	42,200
Specific gravity	*kg/pass.*	261	281

BRIEF DESCRIPTION OF AIRBUS A320 SERIES AND BOEING 737 SERIES

Airbus A320 series [8] includes short-haul and medium-haul narrow-bodied passenger airliners with reactive thrust and dual-engine power plant [4]. The manufacturer is Airbus Corporation. The series is represented by the following modifications: A318, A319, A320, A321, as well as ACJ business jet, a business class aircraft. Airbus A320 is also referred to as A320ceo (current engine option) or A320neo. The final assembly is done in Toulouse (France) and Hamburg (Germany). The capacity is 220 passengers; flying range is from 3,100 km up to 12,000 km depending on the model.

Boeing 737 [9] is an American passenger jet aircraft [5]. It can be the short-haul or medium-haul narrow-bodied airliner with the dual-engine power plant depending on the model. The series includes ten modifications with passenger capacity from 85 up to 215 people. Currently, the company began to manufacture the advanced modifications such as Boeing 737-600, -700, -800 and -900 (737 Next Generation) [15].

BRIEF DESCRIPTION OF THE SINGLE-FUSELAGE AND TWIN-FUSELAGE SCHEMES OF AIRCRAFT

In foreign literature, the term "single-fuselage scheme" is not used, instead, the terms of "wide-bodied" or "narrow-bodied" are applied.

The wide-bodied aircraft is a jet airliner, fuselage width of which allows to place on board not less than two rows of seats, at least 7 seats in one row. The fuselage diameter is typically from 5 to 6 meters (from 16 to 20 feet). The minimum capacity is 200 people, maximum is 850. The width of aircraft of such a configuration is not less than 6 metres (20 feet). The cabin of high-density configuration has the fuselage width is not less than 7 metres.

Originally, the wide-bodied airliners were designed to enhance the level of comfort for passengers and to increase the volume of the transported goods. Then, the airline companies reduced as much as possible the distance between the seats for more profit.

The narrow-bodied aircraft is a jet airliner, fuselage width of which is not less than 4 metres (13 feet). The number of rows of seats is not less than 6. The maximum capacity is 295 passengers (Boeing 757-300).

Based on the analysis made by Flightglobal, the largest web paper on aviation, Boeing Company and Airbus Corporation will maintain a leading position in passenger airliners manufacturing for the period of 2016-2035. Their profit will account at least 1380 billion dollars [7].

The twin-fuselage aircraft configuration is designed with two fuselages separated from each other. The first manufacturer who obtained the patent for the project of twin-fuselage airliner was Airbus Corporation [12]. The uniqueness of this design was that the canard surface was located lower than the rear one. At the same time, the panels had a negative sweep.

Disadvantages of the single-fuselage scheme

The disadvantages of the single-fuselage schemes (SFS) of aircraft that affect the flights safety include:

- accommodation of all passengers in one pressure cockpit, crammed quarters in the cabin when the number of seats in a row is more than four;
- vertical load factor limit due to the significant bending moments in the root section of wing from a distributed air force;
- restrictions on the state of the runway due to the low-engine position;
- restrictions on speed and flight altitude in case of failure of one of engines;
- restrictions on the beam wind when landing with asymmetric power;
- problems in the configuration of the main landing gears on the wing (cutouts in the wing, bays of the retracted position of the main strut that stood proud the fuselage midsection, gear actuation perpendicular to the direction of flight);
- problems when landing with unsafe landing gear.

Twin-fuselage scheme of the aircraft

It is known from the aircraft manufacturing practice about few attempts to use the twin-fuselage scheme (TFS) when designing an aircraft [3]. These are the examples of some projects [13]:

1. **BX.4** trainer aircraft, the designer is Hioni, Russia, 1916

    Structural layout: twin-fuselage biplane with two engines in the fuselage nose section. It had a limited issue;

2. **C-19** attack aircraft, the designer is Sikorski, Russia, 1916

   Structural layout: twin-fuselage biplane with one motor over the center wing section of the lower wing. 2 aircraft were built;

3. **S.55** water aircraft, the designer is Alessandro Marchetti, Italy, 1923

   It was an air-bomber and a scout plane. Structural layout: twin-fuselage and cantilevered high-winged aircraft with one motor over the center wing section of the wing. Serially-produced plane. It had numerous modifications;

4. **BN.1** sporting aerophane, the designer is Pier Nardi, Italy, 1938

   Structural layout: twin-fuselage and cantilevered mid-winged aircraft with two motors in the fuselage nose section. Not serially-produced;

5. **He.111Z** towplane, the designer is Ernst Heinkel, Germany, 1941

   Structural layout: twin-fuselage low-winged monoplane with five engines on the wing. It had a limited issue;

6. **WK.2** carrier aircraft, the designer is Burt Rutan, United States, 2008

   It is designed for the air start of suborbital vehicles.

   Structural layout: twin-fuselage high-winged and cantilevered aircraft with four turbine-powered strut mounted engines under the wing.

None of these aircraft was intended for regular passenger traffic. This is due to the low fuel efficiency of such aircraft. There were some unresolved issues associated with the disadvantages inherent in the twin-fuselage scheme. The main ones are:

- the increased drag run;
- the increased aircraft mass.

However, the optimal design of the twin-fuselage scheme allows to:

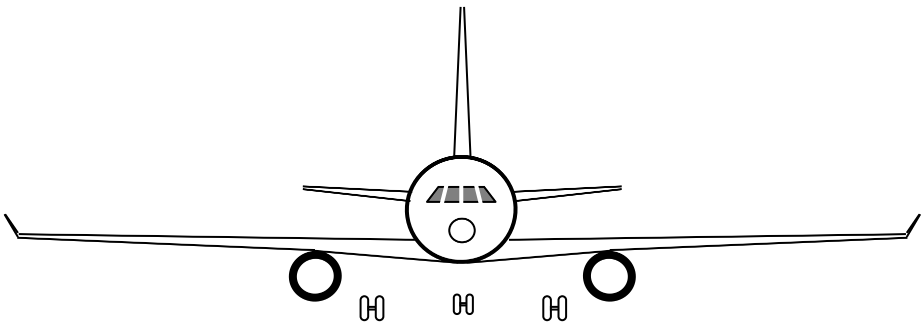
- place the passengers in two independent pressure cockpit;
- improve the interior comfort by cutting down of seats in a row;
- reduce weight and drag run of two fuselages by decreasing their length and diameter at constant passenger capacity and preserving the geometric similarity with fuselage prototype;
- reduce the wing mass by its bending relief;
- increase the wing aspect ratio (aerodynamic efficiency) at the same wing mass similar to the prototype;
- reduce the yaw in case of failure of one of the engines;
- simplify the configuration, to reduce the height and weight of the main landing gear, to ensure retraction of the main landing gear in the direction of flight;
- increase the number of landing gear to four gears;
- ensure the configuration of the power unit over the wing with an odd number of engines;
- get the benefits of security, for example, wheels-up landing, ditching, aircraft decompression, etc.

METHODS

The optional version of the configuration of the twin-fuselage passenger scheme is shown in Figure 2. As the prototype of the medium-haul narrow-bodied airliner, Airbus A320 was chosen. This aircraft with high competitive level of economic efficiency, technical and operational excellence, has a lot of modifications. It meets the requirements of most airline carriers by its technical and economic indicators.

Let us assume that aircraft fuselages of the single-fuselage and twin-fuselage schemes are similar geometrically [18]. Let us also assume that the following parameters of the twin-fuselage aircraft equal to those of the prototype:

- number of passenger seats;
- wing area;
- wingspan;
- fuselage stretch;
- wing taper;
- wing sweep.



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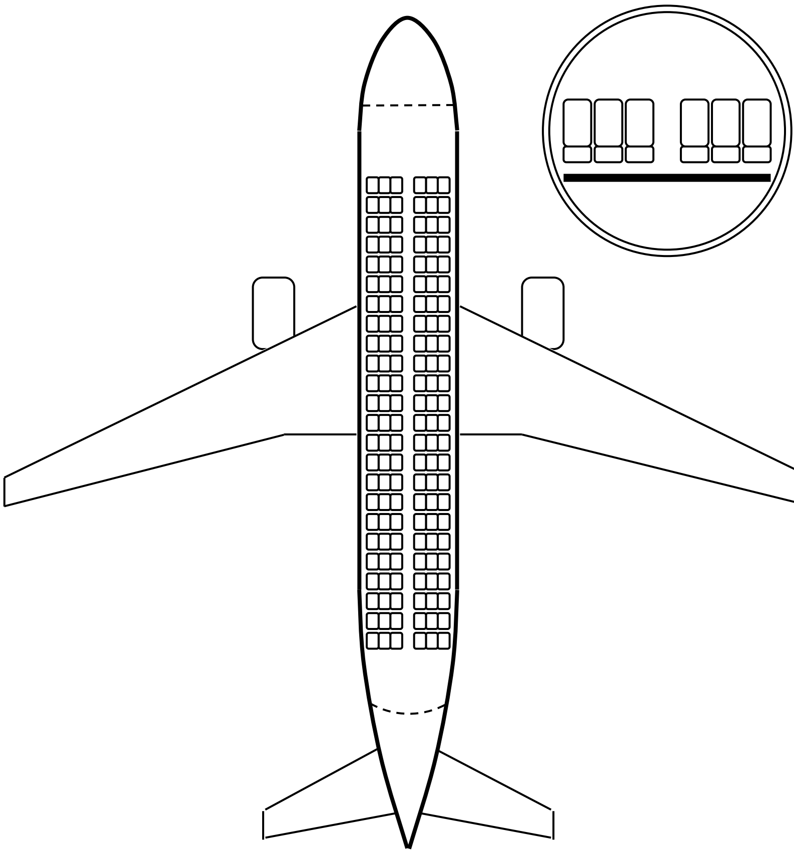
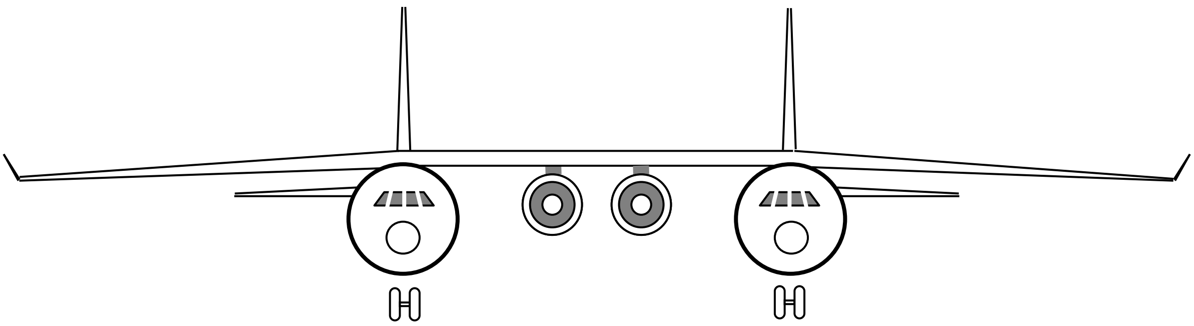


Figure1. The configuration of Airbus A320 passenger aircraft



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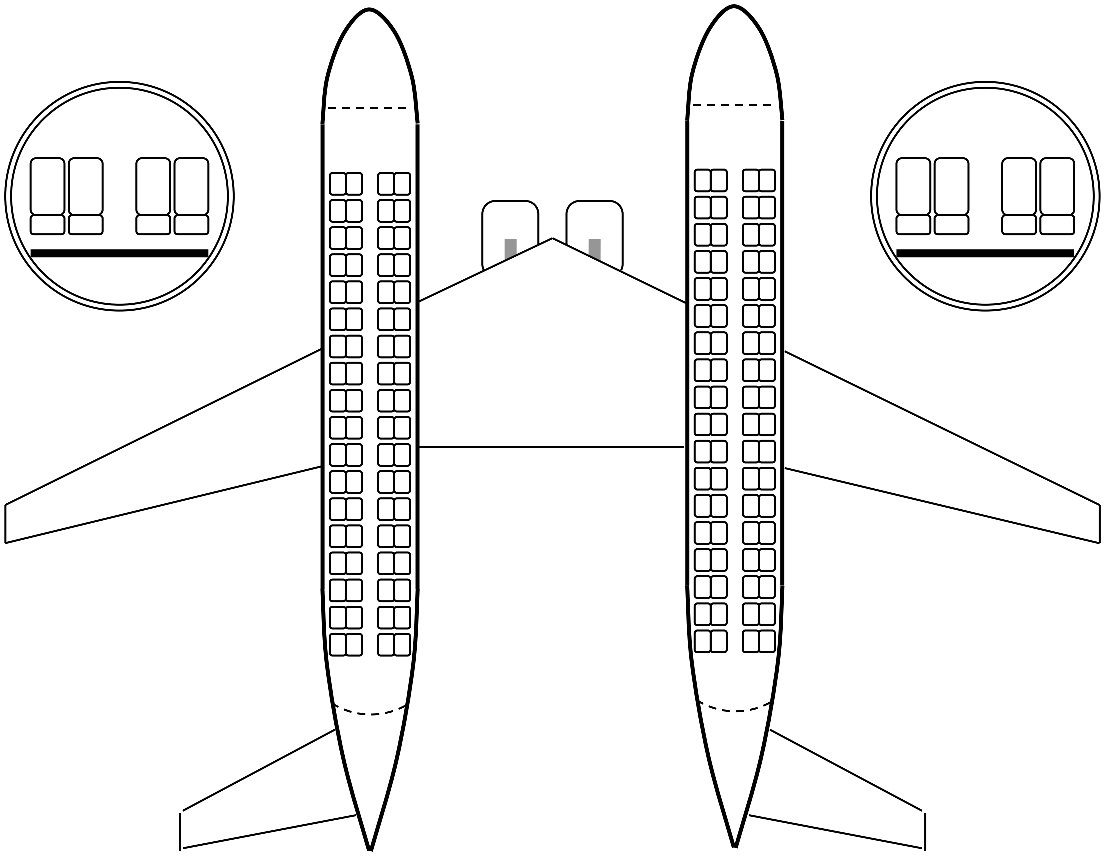

Figure 2. The configuration of the medium-haul twin-fuselage passenger aircraft

RESULTS

Argumentation of the advantages of the twin-fuselage scheme of aircraft

The estimated loading of an airplane wing is determined by the existing strength standards [10]. Figure 3 shows the model law of intensity variation of the span-distributed-load qair force. The bending-moment curve that corresponds to that law is presented in Figure 4.

The reduction of the bending moment from the distributed air force in the root section of wing by the value of ΔMben is typical for the twin-fuselage aircraft, compared to the single-fuselage one [17].

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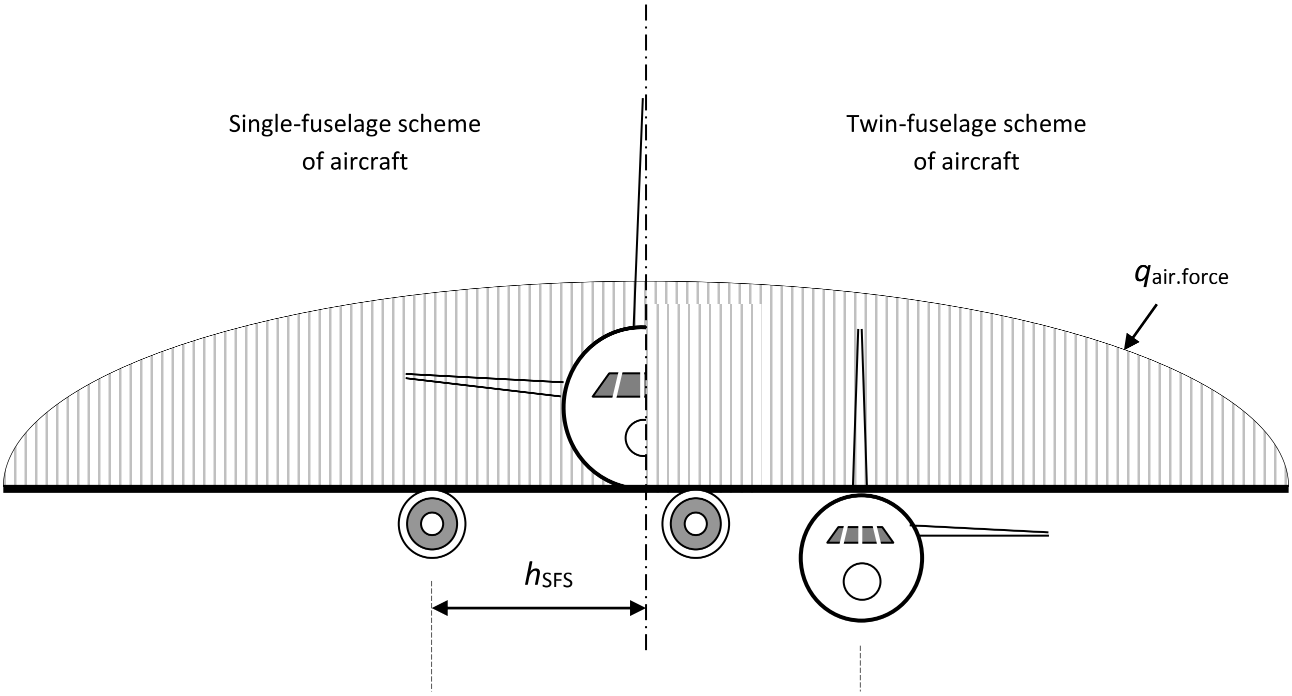

Figure 3. Intensity variation of the span-distributed-load

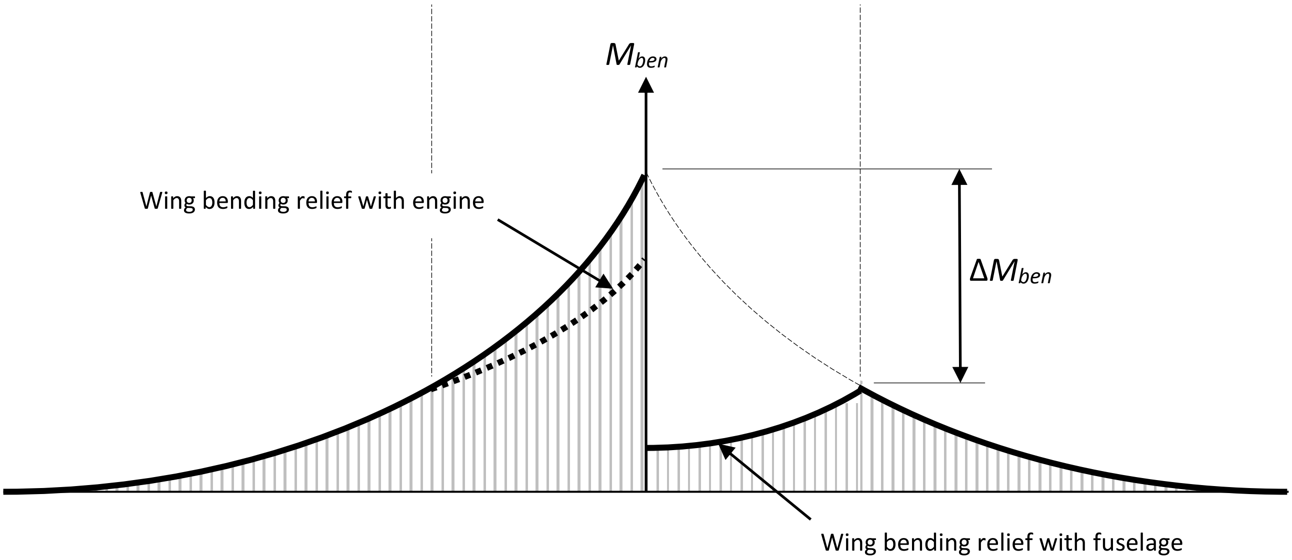

Figure 4. The bending-moments curve

To perform the horizontal flight at given altitude and speed the specific thrust is needed P_r [11]. In case of failure of one of two engines, available thrust is reduced by half (see Figure 5).

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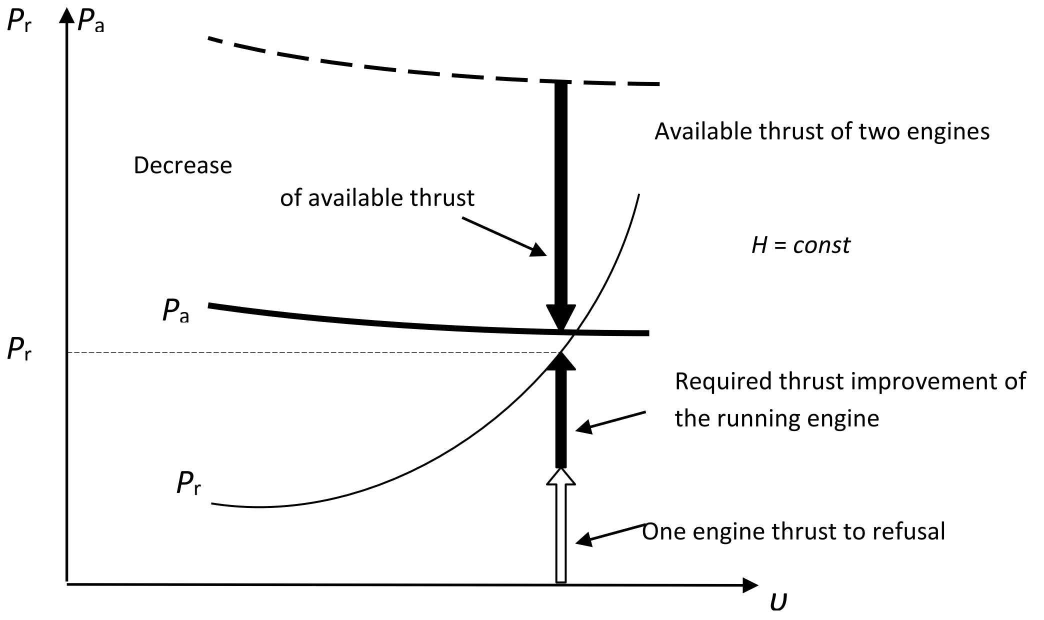

Figure 5. Curves of available and required thrust

To continue flying at given altitude H and velocity υ it is necessary to improve thrust of the running engine by bringing it up to the level corresponding to the required thrust P_r [16].

With thrust improvement, the yaw of the dead engine is increasing $M_{yaw} = P_r \cdot h_{TFS}$. This should be compensated by rudder. To perform these actions, available excess of thrust and rudder effectiveness can be insufficient [14].

DISCUSSION

The proposed twin-fuselage scheme allows to minimize the value of yaw M_{yaw} in case of engine out due to the smallness of the arm h_{TFS} (Figure 6). The practical implementation of the proposed scheme of the aircraft allows to increase the level of flight safety.

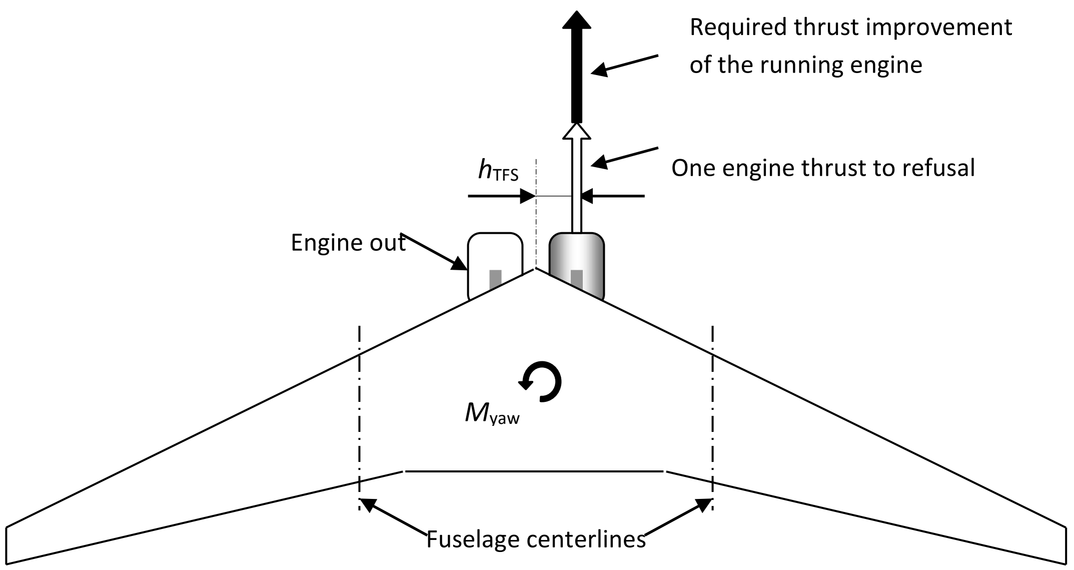

Figure 6. Yaw at engine failure

CONCLUSION

With the unchanged passenger capacity and maintained geometric similarity with the prototype of the fuselage, the configuration of the medium-haul passenger aircraft of the twin-fuselage scheme provides:

- placement of the passengers in two independent pressure cockpit;
- reduction of the number of seats in one row from six to four;
- reduction of the bending moment from the distributed air force in the root section of the wing;
- minimization of yaw at engine failure.

Themes: flight operation of aircraft and flight safety.

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