7. PRELIMINARY DESIGN OF A SINGLE AISLE MEDIUM RANGE AIRCRAFT

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7.1 Introduction

The current available medium range single-aisle aircraft, Boeing 737 and Airbus A320 have been designed over 20 years ago. Despite design updates, a new aircraft is needed to enter service in 2015 It should be able to fly up to 180 passengers to their destination, with a higher level of comfort while offering a reduction of the traveller's ecological footprint.

7.2 Mission objective and key requirements

The aim of this project is to generate a preliminary design of a single aisle medium range aircraft entering in 2015 making use of modern materials and structural technologies.
The design is constrained by several requirements.

- Payload: * 100-180 passengers
  (max. 3 family derivatives)
  * Increased passenger comfort level
  * Less cabin noise

- Environmental: * Lower Fuel Consumption conform Vision 2020
  * Lower Noise Levels conform Vision 2020
  * Lower Emissions conform Vision 2020
- Structures: * 15% weight reduction for the main wing
  * 15% weight reduction for the fuselage
- Financial: * Lower recurring cost
  * Lower Total life cycle costs

7.3 Concepts

To determine which concept would perform in the best manner, taking into account the requirements, a design option tree was constructed. First the ‘obvious losers’ were determined and the good concepts were chosen. Three concepts were selected for the trade-off: the blended wing, the joined wing and the conventional configuration.

The blended wing was considered a non feasible design since it’s not a feasible option for the single aisle range aircraft, transporting no more than 180 passengers and entering service in 2015. To get it to fly and certified will require huge development cost and resources. Furthermore, the blended wing becomes efficient for 500 or more passengers. Huge cost and little improved efficiency both add to the risk but above all: it makes it impossible to turn this concept into a profitable product.

The joined wing is aerodynamically very efficient. The wings were designed in the form of a box, which reduces the induced drag, therefore lowering fuel consumption. Two wing boxes are required however and the landing gear cannot be placed under the wings, requiring strengthening of the fuselage. A heavier structure is the result. The joined wing has been tested in the wind tunnel but it is not yet produced. This means large investments are needed to make it perform according to the requirements, making it inferior to the conventional concept.

The conventional concept was chosen in the trade-off. It has the lowest research & development costs, the lowest production costs and it is well known. There is hardly any risk involved for an introduction in 2015 and it has good prospects of meeting the other requirements.

7.4 Material Selection

In this section the material for parts of the aircraft will be selected. First a pre-selection of materials will be made. After this the design philosophy and criteria for parts will be discussed. Finally the results of the trade-off will be covered.

Materials pre-selection

Many materials are proposed to be used in aerospace applications. A global pre-selection is performed in order to continue with only those materials that are suitable for aerospace applications and are sufficiently developed so that is it feasible to use them for an aircraft that has to enter service in 2015. The result of the pre-selection:

- Aluminium 2000-series
- Aluminium 7000-series
- Maraging steel
- Titanium
- Carbon Fibre Reinforced Plastics
- Glass Fibre Reinforced Plastics
- Glare

Design philosophy and criteria

The design philosophy generally used in aircraft design is the fail-safe philosophy. This philosophy states that parts are allowed to have defects. However these defects may not compromise the structural integrity. This philosophy has been used for fuselage, main wing and empennage. This philosophy imposes some requirements for the materials. These requirements are high fracture toughness and low fatigue crack growth.

Another design philosophy is safe-life. This philosophy states that a part will not fail during life. This imposes over dimensioning of the part and is generally only used for parts that are difficult to repair or replace. This philosophy has been used for designing the centre wing box.

Other criteria for the specific parts of the aircraft are:

Fuselage:	fatigue, corrosion, impact, costs, inspection and reparability
Main wing:	fatigue, corrosion, stiffness, impact, costs, inspection and reparability
Empennage:	fatigue, corrosion, impact, costs, inspection and reparability
Centre wing box:	fatigue, corrosion, costs

A final criterion is the matching stiffness between connecting parts, to prevent uneven loading.

A summary of the criteria used for selecting the materials of parts is given below. Each criterion is given a weight factor for each part, since the importance is highly dependent on the position and load cases of the part. The used criteria:

- Corrosion
- Fatigue
- Fracture toughness
- Impact
- Specific shear strength
- Specific tensile strength
- Specific compressive yield strength
- E modulus
- Buckling
- Development costs
- Material costs
- Manufacturing costs
- Inspectability
- Reparability

Results from the trade-off

The results from the trade-off are presented in the table below:

Fuselage	
Fuselage upper skin	Glare
Fuselage side skin	Glare
Fuselage lower skin	Glare
Fuselage upper stringers	Glare
Fuselage lower stringers	Glare
Fuselage frames	Aluminium
Cargo floor	Glare
Cabin floor	Glare
Main Wing	
Leading edge	Glare
Skin	Glare
Front spar	Aluminium
Rear spar	Aluminium
Stringers	Glare
Ribs	Aluminium
Engine pylons	Titanium
Empennage	
Leading edges	Glare
Horizontal tail skin	Carbon Fibre sandwich
Vertical tail skin	Carbon Fibre sandwich
Horizontal tail spars	Carbon Fibre
Vertical tail spars	Carbon Fibre
Horizontal tail ribs	Carbon Fibre sandwich
Vertical tail ribs	Carbon Fibre sandwich
Wing box	
Front spar	Carbon Fibre
Rear spar	Carbon Fibre
Span-wise beams	Carbon Fibre
Skin	Carbon Fibre
Stringers	Carbon Fibre
Ribs	Carbon Fibre

Table 7.1: Results from trade-off

7.5 Structural Characteristics

The aircraft has to be able to withstand all loads that it will encounter during its lifetime. One can imagine that many different types of loads will act on the aircraft during all its flight operations. For this reason, several load cases have been chosen that will represent the most severe loads on the aircraft. Each load case will be mentioned here, after which the most severe one will be applied on simplified models of (part of) the aircraft to obtain the maximum stresses. These stresses will then allow the minimum necessary thicknesses of each component to be computed.

The load cases considered:

- Flight manoeuvre loads
- Gust loads
- Landing loads
- Pressure differential loads
- Braked roll loads
- Towing loads
- Side slipping loads

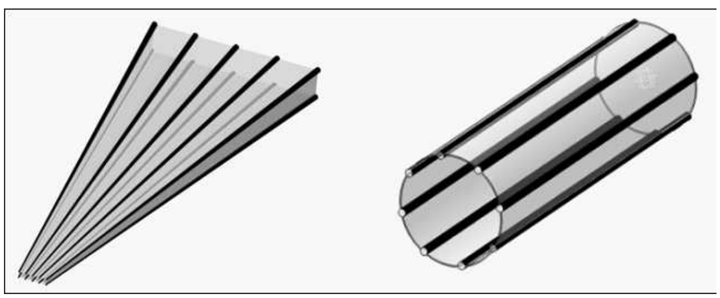

Figure 7.1: wing and fuselage models

These load cases can be applied on the wing and fuselage models resulting in normal stresses and shear flows, which are compared to the allowable stresses (yield strength, buckling strength or fatigue strength whichever is lowest). The most severe load case will result in the minimum necessary thicknesses and thus in the minimum weight.
Comparison is made between a conventional aluminium wing and a glare-aluminium wing to find the weight saving that can be achieved; the same is done for the fuselage.

With the equations and method used here for calculating the structural weight of the fuselage, a reduction in weight of 20 % is achieved by using modern materials, with a target of 15 % weight saving. Since many safety and manufacturing aspects of newer materials have not been taken into account, this value of 20 % might be too optimistic, but even then a substantial weight reduction is expected.
The weight of the wing is only reduced slightly with the use of Fibre Metal Laminates since the weakest material in the structure limits the other materials. A full FML wing therefore would be the ideal solution; but because of production reasons this is not a feasible alternative.
The weight calculated by the program of the fuselage is (for both the aluminium and FML) too high, which would indicate that some modifications have to be made, but could not be performed within the available time for this assignment.

7.6 Conclusions and recommendations

Conclusions
The aim of this project was to generate a preliminary design of single aisle medium range aircraft entering in 2015 making use of modern materials and structural technologies. The requirements set in the introduction were met as follows.

The payload requirements were met by preliminary designing an aircraft with a conventional configuration for 150 passengers. Family derivatives are easy to generate with this configuration by lengthening or shortening the fuselage in front or behind the wing. Further the pitch and seat width was increased. The cabin noise level was decreased by making use of lower noise level engines.

The environmental requirements were met by using modern engines. These engines will be 15% more fuel efficient and produce less noise as mentioned in the payload requirements. Furthermore the overall level of emissions of these engines will be lower. Finally the weight reduction discussed in the following section will cause the aircraft to need less fuel and hence make the design more environmentally friendly.

The structural requirements were met by the use of modern technologies and materials. Large aircraft components will be produced from other material than aluminium. The wing will consist of aluminium and fibre metal laminates (Glare). The fuselage structure is primarily built from fibre metal laminates (Glare). Only the fuselage frames still are made from aluminium. Further the empennage will consist of carbon fibre reinforced plastics. With these new materials it was estimated that the wing structural weight could be reduced by 3%. The structural weight of the fuselage could be reduced up to 20%.
Also during the preliminary weight estimation aerodynamic, higher Lift / Drag values and propulsive, lower fuel consumption, improvements were taken into account. This resulted in lower structural mass of 12%.

The financial requirements of reducing the total life cycle cost and recurring cost were estimated to be reduced by 8%. This was primarily due the fact that Glare requires less maintenance.

Recommendations

In this project the aerodynamic and propulsive weight reduction and the structural weight reduction were estimated independently. These estimations can be improved by taking both estimations together and including the snowball effect. Furthermore the preliminary estimation of the aerodynamic and propulsive weight reduction should be investigated further for more accurate results. Also some safety factors should be included in further research work. FEM models should be used for following computations of the weight.