Morpheus

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1 Introduction

Over the last few decades aviation has grown significantly. Air transport has become a very efficient and safe way of travelling. This increase in air transport comes with a drawback. A rising awareness of the general public about environmental sustainability will imply new constraints on air traffic. Aircraft should be fuel efficient, have low environmental impact and be quiet. Therefore the design of new aircraft should emphasise two primary requirements, high cruise efficiency for fuel consumption and low take off and landing noise. This results in one of the design traits of Morpheus, incorporating cutting-edge morphing technologies.

2 Design objectives, requirements and mission statement

Design requirements	**Values**	**Mission requirements**	**Values**
Unit Production Costs:	$250 million	Range:	15 000 km
Number of units:	500	Cruising speed:	900 km/h at 12000 km
No. of passengers incl. pilot:	250 plus 10 crew	Max. take-off length:	2700 m
First Flight:	2015		
Min. Life span:	30 years, 150 000h, 25 000 flights		

Performance Requirements:

- Noise level not exceeding sideline EPNL 86 dB
- Optimise cruise performance for fuel consumption
- Investigate the use of adaptive aerospace structures technologies to reduce take-off noise and improved fuel efficiency

With these design objectives and requirements the following mission statement is formulated:

"Preliminary design of a transonic, transatlantic, 250-seater aircraft using morphing wing technologies optimised for reduction in take-off noise and fuel efficiency in cruise, incorporating emphasis on sustainability with first flight in December 2015 at a unit cost of $250M."

3 Market needs analysis

Airbus, Boeing and the FAA project an increase in air traffic. Both Airbus and Boeing aim to produce more than 500 aircraft seating 250 passengers. As the Morpheus will be in direct competition with these manufacturers and because it would be hard to take market share away from them, the Morpheus team is projecting that 500 units be produced, with a possibility of increasing production.

As mentioned by Boeing, noise and emissions reduction are becoming mandatory requirements as the demand for quieter aircraft will increase by the year 2015. This makes the Morpheus well suited for the civil aviation market. As the market will already include the Airbus A350 and the Boeing 787 it is important for the IDSE team to ensure that the Morpheus is efficient and proves competitive. However, because these aircraft are yet to achieve first flight there is potential for the Morpheus project to make headway in this competitive market.

4 Concept development

After investigating the current possibilities of morphing it has become clear that these new technologies can be implemented in a wide range of aircraft. Therefore, the choice is made to first focus on deciding on a aircraft configuration from a number of possible options before implementing the morphing capabilities which are demanded by the customer.

In order to limit the design to an applicable focus field, a number of aspects, derived from the requirements were taken into account. These included transonic effects for the design of the aircraft, use of different configurations and layouts, engine placement for reduced noise and material selection. Different concept design options were discussed and chosen. The designs (see Figure 1) proposed included a canard, twin fuselage, conventional and a Blended Wing Body. These were chosen on the basis of feasibility of fulfilling requirements. The range of designs can be seen to be quite large, this was to ensure a broad spectrum of options to be investigated before selecting the final concept.

A trade-off study was done, incorporating if the design met the design emphases and the associated technical risks. The result of this trade-off study indicated that the conventional design was strongest in most field, as was chosen for final concept development. Reasons enumerated in this chapter included its low technical risk, feasibility, and its ability to meet design and performance requirements.

Figure 1: Concepts

5 Final concept (3)

The design of Morpheus employs a wide range of new technologies to improve its fuel efficiency, reduce its environmental pollution and decrease the nuisance caused by aircraft noise. Moreover the passenger comfort and the Reliability, Availability, Maintenance and Safety (RAMS) are significantly improved by selecting next generation aircraft materials and clever design. In this chapter the overall design of Morpheus, its new technologies and - design solutions will be presented. Below in Figure 20.2 the 3D design of Morpheus is shown.

Figure 2: Morpheus

Passenger accommodation

The Morpheus will be based on a conventional layout. The optimal fuselage diameter and length are determined in such a way to accommodate all passengers, crew and payload in relative comfort, while still providing favourable aerodynamic characteristics. A three class configuration was assumed during the design to be able to accommodate all possible passenger groups. Moreover, to further improve the passenger comfort, large window will be installed. This combined with a higher relative humidity, flight at lower pressure altitudes and high performance air filters will ensure that the passenger comfort of Morpheus will be competitive in the future aircraft market (Hawk, 2005).

Morphing wing design

The aerodynamic design of Morpheus is highly optimized increasing its fuel efficiency, while at the same time reducing its noise production. This is accomplished by implementing a morphing wing with supercritical aerofoils and an optimized planform. During cruise the wing will morph. The chord length will be decreased with 15% by moving the rear section of the entire wing forward, and thereby decreasing the wing surface. This will result in a decrease in lift and therefore a decrease in induced drag. However, since the absolute wing surface decreases, also the skin friction drag will decrease. Moreover, the morphing design allows for an improved cruising strategy, eliminating the need for a climbing cruise. During take-off and landing the rear half of the wing will move not only forward but also rotate down, see figure 3. This system makes the use of conventional high lift devices, like flaps and slats, obsolete.

The aerodynamic efficiency is improved even further since all aerodynamic surfaces will be of a seamless design with no obstacles generating extra drag during cruise. The seamless design will also eliminate the notable noise produced around conventional flaps during take-off and landing. Further noise reduction is accomplished by designing an aerodynamic fairing around the landing gear, since during landing as much as 25% of the noise is produced by the landing gear (U.S. Pat. No. 2,180,462 A, 2004).

Control and stability of Morpheus is guaranteed by morphing the camber of the aerodynamic surfaces (Bartley-Cho et al., 2004). Also explicit attention is paid to the implications of the morphing wing on the sizing of the tail- and control surface areas to ensure stable and safe flight characteristics. A Fly-By-Wire (FBW) system with adaptive control laws will ensure a good response during all situations.

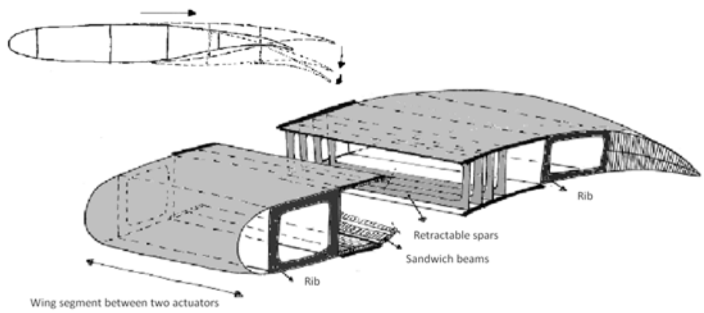

Figure 3: morphing wing 2d and 3d representation

Propulsion and performance

The propulsive force of Morpheus will be provided by two Trent 1000-C1 engines that are modified to improve the fuel efficiency and reduce engine noise. This is accomplished by applying a negatively scarfed and morphing intake (Baker and Bewick, 2001 and Pitt, cited by Steenhuizen, 2007) and Helmholtz resonators within the engine, and optimized exhaust chevrons to reduce the noise (Mengle, Elkoby, Brusnia, 1991). The scarfed intake alone will result in noise reductions of 5 – 6 dB. Because of the efficient aerodynamic and morphing design, and highly efficient engines Morpheus will need significantly less fuel and be able to fly missions with a maximum range of over 15000 km (MTOW).

Structural design and materials

During the design explicit attention was paid to the morphing structure and its implications. The design, shown in figure 3, includes a feasible and effective morphing structure. The wing structure will have two torsion boxes, where the rear torsion box can be moved horizontally and downward. The section between the two wing boxes consists of sandwich beams suspended from a retractable rail. The top and bottom skin of the mid section are constrained to each other by the retractable spars.

Morpheus will make extensive use of highly cost effective engineering thermoplastic sandwich structures with variable stiffness facings. Since the equal weight design philosophy (Tooren, 1998) is applied, the resulting structure will have a lower production cost, increased reliability and a higher safety. Moreover, during the design attention was paid to the accessibility of the morphing structure. The time between inspections can be further extended by the use of effective damage (for example: delamination) stoppers. Another important benefit of engineering thermoplastic composites is the increased safety as they have excellent fire-smoke-toxicity properties (Bersee, Niño (eds.) et al., 2006).

Morpheus key values	Value	Unit	Morpheus key values	Value	Unit
Fuselage diameter	6.0	m	Aspect ratio min/max	10.5/12	-
Fuselage length	62.3	m	MAC min/max	5.73/6.59	m
Wing span	69.2	m	Taper ratio	0.2	-
Wing area min/max	397/ 456	m^2	Root Chord min/max	8.32/ 9.57	m
Vertical tail area	68.4	m^2	Tip Chord min/max	1.66/1.91	m
Horizontal tail area	91.2	m^2	Quarter Chord Sweep	32.1	deg
			Lift coefficient TO	2.65	-
Maximum Take Off Weight	2580.3	kN	Lift coefficient landing	1.78	-
Maximum Take Off Thrust per engine	310.5	kN	Lift coefficient cruise	0.478	-
Fuel Weight	1147.2	kN	Drag coefficient	0.0287	-
			Lift/Drag ratio	19.25	-
Range	15000	km			
Payload	250070	N			
No. of passengers	250	-			
Cruise speed	250	m/s			

Table 1: Overview of Morpheus key values

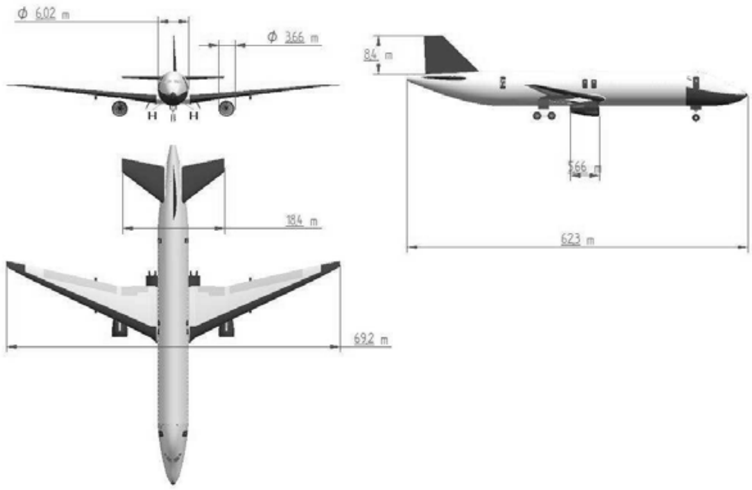

Figure 4: 3 side view of Morpheus

6 Conclusion

Before the technical calculations were performed a decision on the overall design of Morpheus was developed. The ideas for the morphing were key to the design and the morphing strategy was required so that each design area could analyse the aircraft whilst knowing exactly what would happen during flight. To conclude the morphing strategy, Morpheus will have a seamless wing creating less drag and increasing fuel efficiency. The wing will reduce in area throughout cruise, negating the need for cruise climb, and minimizing the drag penalty by reducing the wing surface area. This will also optimise the lift produced. Morphing technology has been used to change the shape of the aerofoil, from a takeoff setting simulating flaps, to a cruise setting of a supercritical aerofoil shape, to the landing configuration. It is also being used for the primary control surfaces, to give the advantage of seamless joints and more aerodynamically shaped structures.

The main conclusion to be drawn from the performance, weight and balance analysis is that the maximum takeoff weight of the aircraft is 2.58 MN. A fuel weight of 1.15 MN is required to ensure that Morpheus meets the range requirement of 15,000 km. Concluding the propulsion analysis Morpheus will use the latest engines developed by Rolls-Royce, the Trent 1000, which along with scarfed inlet nacelles, will help to reduce sideline noise of the aircraft and will increase the efficiency of Morpheus. This makes Morpheus competitive within the current airline industry.

The aerofoil chosen is the NASA SC20714 supercritical aerofoil. This was stretched in accordance with the morphing strategy and a maximum extension of 15% was deemed appropriate to produce the sufficient results required by the project. The wing was optimised for cruise performance and resulted in a maximum wing area of 456m^2 and a minimum wing area of 397 m^2. Pop-up vortex generators and landing gear fairings were also deemed necessary for Morpheus.

The first conclusion to be drawn from the stability and control analysis is the shape of the tail of Morpheus. This is a conventional inverted T-tail. The main outcome of the stability calculations was the sizing of the empennage to ensure that Morpheus will be stable and controllable at all stages during flight, including when the morphing takes place. The vertical tail size is higher compared to similar aircraft, but this is mainly due to the high maximum wing area in morphed condition. As well as the sizing of the empennage, the control surfaces of the aircraft were looked at, with emphasis on the ailerons as the morphing concept has meant that the ailerons will be seamless. A cambering trailing edge mechanism is used over the entire span to ensure roll control. Besides roll control, this mechanism can at the same time be used to influence the lift distribution over the wing.

The main structure of the wing, and the most complicated part of the design, is the double wing box. This double wing box, and moving aft wing box, is what creates the end result of a 15% wing chord extension. The structures group calculated that should it be needed it is capable to extend it further to 30% chord extension. The structures group also looked at the materials that would be used in the design of Morpheus, from adaptive materials, to composites, and the conclusion is that Morpheus will be made of approximately 70%-80% composite materials. The carbon footprint of Morpheus is lower than it could have been as aluminium was selected as the main material. However, the life cycle assessment needs to be revised in more detail within the detailed design phase.

7 Recommendations

This section aims to give recommendations for the future development of Morpheus. It is hoped that should the project continue past this preliminary design stage that these recommendations be undertaken to ensure the design is correct and that the client requirements are met.

- The Breguet range equation is an assumption that was made in parts of the technical calculations. Further investigation into the Breguet equation is needed to ensure that this assumption is valid.
- A short, qualitative, life cycle assessment was presented. However future development requires a detailed investigation so that conclusive results can be presented and to make clear that the impact of Morpheus on the environment is minimal.
- A comparison of Morpheus cruise data with conventional cruise climb aircraft should be completed to further back the conclusion that the morphing of this aircraft is beneficial to the client.
- The forces required to rotate on takeoff should be calculated to ensure that the undercarriage is not too far aft on the fuselage.

- Designs will be commissioned to find the most suitable method for undercarriage storage within the fuselage.
- Flutter phenomena should be further investigated to ensure that it will not be a big problem for Morpheus.
- More emphasis and focus should be put on the morphing technologies in order for the aircraft to be ready for flight testing by 2015.
- 10 degrees deflection of the roll control mechanism were left over for other purposes. Further investigation in aerodynamics may show what can be done using this deflection to improve the lift distribution over the wing.

8 References

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