Theoretical Proposal of the Engine for HALE Unmanned Aerial Vehicles

Abstract

The turn of the first and second millennium brought development of many technologies. One of these technologies are unmanned aerial vehicles. Success in armies meant an expansion into the civil sector. Requirements for rapid installation into an armament and costs as low as possible meant the usage of current aircraft engines without any further modifications. Especially in an effort to achieve maximal altitude of the vehicle the engine without the modification could be a cause of unsuccessful effort of exploitation of vehicle´s options. Simple analyses of the vehicles and their current propulsion systems were found significant elements of their interconnections. Then the currently appropriate propulsion systems were assigned with a choice justification and its possible alternatives, hazards, various advantages and so on. Then a type of the engine which has not been fully utilized on these vehicles yet was theoretically designed. The point that this engine has not been fully utilized on these vehicles is precisely why it could bring new benefits to this area. It could even outweigh the advantages of the engines currently used on these vehicles and potentially replace some of them. This part of the theoretical engine design is the subject of this article.

KEY WORDS: *UAS, UAV, HALE UAV, unmanned vehicles with high ceiling, propulsion systems, aircraft engines*

1. Introduction

Unmanned vehicles are considered as one of the latest technological advances. Although they have been beside the constructions piloted directly from the deck since their beginnings, due to the technological challenges arising from the specifics, mainly of the remote control, unmanned structures had been pushed away to the edge of interest for decades. Further development of optics and communication tools at the end of the 20th century finally meant extending of their possibilities and with that related roles. Thanks to the military missions as well as the penetration of the civilian market unmanned vehicles were brought to the forefront by both military and potential airline users but also the media and the general public. Another development caused by this current state is the subject of this article.

1.1. Division of Unmanned Aerial Vehicles

One of the most important and most commonly used aspect according to that the unmanned vehicles are divided is ceiling and distance range. These two parameters characterize their ability to perform the most frequent missions and tasks. It is precisely the group that reaches the highest values of ceiling and endurance, named as High Altitude Long Endurance (HALE), of further interest. This group includes vehicles that have at least 15 km ceiling and endurance of up to 20 hours [2].

2. Proposal of a HALE Unmanned Aerial Vehicle

In order to select the appropriate propulsion system used in the subsequent design of the engine itself, the current state of HALE unmanned devices was monitored and then a possible area of interest was identified from this analysis. This would be the uncovered area of speed, ceiling or other characteristics that the proposed engine could potentially provide to the HALE unmanned vehicles. The graph for the power units used by the UAV and their dependency on the Mach flight number and ceiling shows one of these areas (Fig. 1). This area is characterized by velocities ranging from 0.3 to 0.5 Mach and ceiling about 15 kilometers. The above-mentioned speed range at lower altitudes is covered by the turboprop drive. For this propulsion system are currently laid ceiling limits about 15 kilometers above sea level. Unfortunately, in the vast majority of cases this limit is mentioned as a mere fact without further explanation. Therefore, further in the chapter is a discussion about the causes of the current state and the possible solutions that could be made for turboprop motors to be competent for this type of aircraft constructions. However, the complexity of this topic far outweighs the scope of this article and therefore contains only basic information that should be further confirmed and extended by more detailed research and calculations.

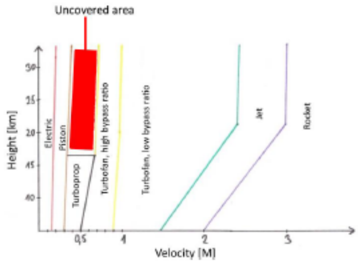

Fig. 1 The diagram of dependency of the use of different engines in unmanned vehicles for different flight velocities and altitudes

Typically, the air engine design process begins with the document of the so-called Request for Proposal (RFP). It lists the customer's requirements for the final flight parameters and capabilities of the airplane that the proposed engine should provide. A simplified demonstrational request for the proposal is the subject of the following lines [4].

2.1. Division of Unmanned Aerial Vehicles

The flight profile (Fig. 2) with the specified phase conditions should be as close as possible to the future use of the vehicle. During making of this model flight it is also necessary to take into account all flight modes that are expected to be very likely to occur in much of the flights. Model flight should therefore be a combination of phases (Table 1) and modes of each flight of different purposes and tasks. This ensures that the propulsion unit will receive the characteristics that will ensure the most appropriate operation for the vast majority of flights. Based on its parameters it is necessary to determine whether the turboprop drive would be suitable and capable of providing the necessary characteristics (Table 2) [4].

Table 1

Flight profile by phases (modes) [4]

Phase	Description, requirements
1-2	Take-off. The airport is located at 380 m above sea level at 15°C. Take-off length ≤ 2 000 m on dry paved runway.
2-3	Pitch. Minimum climb time to the ideal flight height and to achieve the ideal speed at this height.
3-4	Flight to the operating area. Achievement of an operating space 1000 km away at a time of ≤ 4 hours.
4-5	Endurance in the operating area. Circling above the operating area at a height of 14 km at the longest endurance time of the vehicle. Turning time 2 hours.
5-6	Flight in the operating area. Height 15 km, duration 4 hours. Part of payload is thrown away.
6-7	Endurance in the operating area. Circling over the operating area at a height of 16 km at the longest endurance time of the vehicle. Turning time 3 hours.
7-8	Flight in the operating area. Height 16 km, duration 5 hours.
8-9	Flight from the operating area. Minimum downtime to the ideal altitude and to achieve the ideal speed at this height. Reaching the descent space 1000 km away at time ≤ 4 hours.
9-10	Descent and landing. The airport is located at 380 m above sea level at 15°C. Minimum down time to the beginning of the landing approach. Landing length ≤ 2,000 m on dry, paved runway.

Table 2

Characteristics / performance [4]

Element/operation	Requirement
Payload	300 kg of scientific equipment
Endurance	32 hours
Ceiling	17 km
Take off distance*	2 000 m
Landing distance*	2 000 m
* The airport is located at 380 m above sea level at 15°C.	

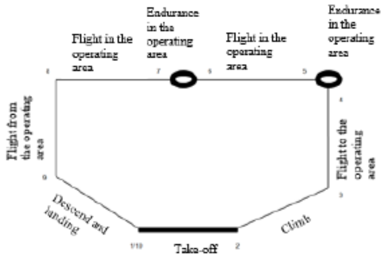

Fig. 2 Model flight profile [4]

Another requirements

Maintenance - The proposed engine must allow easy control, accessibility and disassembly of major elements of all major systems.

Fuel - In the case of a conventional propulsion system, standard fuel such as JP-8, Jet-A, or the like.

2.2. Turboprop Engine

The model flight demonstrates that the turboprop flight could be an interesting alternative because of its low specific fuel consumption especially among its HALE.

As previously mentioned the turboprop engine could fill an empty space between HALE unmanned vehicles. The fact that this area between piston and two-stroke engines is significant proves the amount of low speed requirements for these vehicles. Therefore, it is certainly not the ideal state of non-fulfillment of the range of speeds that at the lower limit is still quite suitable for the purposes of preferring or requiring lower speeds and on the contrary the upper limit already meets the preferences of higher speed purposes. However, this is by no means the only possible reason for go for turboprop engine installation into the HALE.

Ceiling

The turboprop drive consists of an engine essentially similar to a jet engine and a propeller. This kind of propulsion would also be likened to a two-stream engine with a huge bypass ratio. However, while the fan is located inside the engine casing, the turboprop engine propeller is located outside the engine itself. Despite the many differences the parts of the turboprop engine and the engine as a whole work in much the same way as the propulsion systems already used in the HALE. Theoretically, the turboprop engine should be able to reach between 15 and 20 km.

The main problem is a change in the state of a working fluid with a change of flight height. Piston engines turbocharged with multi-stage turbochargers operate at an altitude of more than 15 km with a working fluid whose status corresponds to sea level. Turboprop engines intake the working fluid of a level corresponding to the height of the flight. Increasing flight height deepens the problem. Of course, this problem affects jet and turbofan engines as well. Their advantage over turboprops is that the higher amount of suction working fluid, higher compression ratio and acceleration of the working fluid in the engine [3].

2.3. Construction

The design is done only very roughly by describing the required characteristics of individual components of the engine of the turboprop engine.

Air inlet

The air intake should ensure that sufficient air is supplied during all phases of the flight. It is also very important to minimize the loss of energy of air flow. The intake should be aerodynamically shaped to produce the lowest value of resistance. Due to the speeds of the air flow, it will be a subsonic type of device. This type is in most cases unregulated. From the definition of the mass flow that is the product of the cross section through that the current passes and its density and velocity it is obvious that there are three ways to increase its overall value. Any increase in cross-section, density or velocity value means an increase in the total mass flow rate. However, the speed can only be increased to certain limit values when the supersonic speeds are achieved and the energy losses become disproportionate. Influencing the density of the air flow in and out of the input box without the use of paddle machines is possible in a very limited amount. The last option is to increase the cross section of the incoming air. However, regulating intakes are currently used to

Air outlet

This part is far less important than at jet and turbofan engines. The primary thrust is created by a propeller and the outlet creates a thrust of only lower values or even none. In spite of this it is necessary to optimize the system in order to obtain the maximum value of the energy transformation of the gas flow to the force and hence to the total thrust when utilizing the system for creating the secondary thrust as discussed in the previous part [1, 3, 7, 8].

3. Conclusions

Theoretically, it seems that even turboprop propulsion unit could be a suitable propulsion system for the unmanned HALE vehicles. In spite of the improved ceiling limit it would rather be a vehicle somewhere between the HALE and a MALE (Medium Altitude Long Endurance) classification. The ceiling would most likely not exceed 20 km but due to the distribution of current HALE UAV availability, it is an absolutely acceptable value. However, in order to confirm the feasibility many further studies, calculations and tests are needed to confirm or refuse this conclusion.

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