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Analysis of VTOL UAV Propellant Technology

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Abstract

Recently, the surge in the interests in unmanned aerial vehicles has soared dramatically worldwide due to many potential benefits foreseen by this technology. The most widespread use of the commercial drones is a multi-copter form of unmanned aerial vehicle, because of its vertical takeoff and landing (VTOL) capability. However, due to the structural characteristics, it has a disadvantage that the flight time is quite short, which is typically ranging between 15 to 30 minutes. The fixed wing type of unmanned aerial vehicles has a longer flight time and duration, but it is not easy to secure a safe landing space, especially in the city areas. For this reason, demand for vertical fixed take-off and landing aircraft is rapidly increasing throughout the world. This study analyzes the trends and recent development of global VTOL technology and provides a direction into which the current state of the technology should be heading. By comparing the advantage and disadvantage of various VTOP propulsion types, we can clearly identify the most effective form of VTOL propulsion types. Such analysis will be highly beneficial to the drone researchers and scientists in terms of future development.

Keywords

VTOL, UAV, Tail Sitter, Tilt Wing, Fixed Wing, Tiltrotor, Vertical Takeoff and Landing

1. Introduction

One can clearly see the recent surge and wide applications of unmanned aerial vehicles in many areas, such as agriculture, forestry, surveillance, rescue operations, security, aerial photographing, and so on. The most widespread use of the commercial drones is a multi-copter type of unmanned aerial vehicle. For example, most aerial photography drones are this type. It is because this type of drones doesn't require a length runway and it can hover in the air while filming. This kind of convenience is necessary, especially in the congested areas like city centers. However, it has a disadvantage that the flight time is too short (typically ranging between 15 to 30 minutes). The fixed wing type drones can stay afloat for a much longer time, typically over 1 or 2 hours. However, it is not always easy to find a safe landing space, and it is not easy to manually control this type of drones [1] [2]. Due to these reasons, the most commercial drones are multi-copter types.

The third type of unmanned aerial vehicle is often referred to as a VTOL drone, which can vertically takeoff and land, while flies like a fixed-wing aircraft once airborne. It doesn't require a runway, and land like a helicopter. The VTOL drone can hover in the air, yet capable of flying a much longer time. Due to these advantages, the VTOL drone is taking a great interest among researchers and commercial applications. In order for VTOL drones to hover and make a transit flight like airplane, its propulsion system should be very different than those of multi-copter type drone or fixed-wing type drones. Our initial analysis shows that there are so many varieties already developed, while a thorough study of analyzing VTOL types is not present until this time. In this regard, our goal is to collect the different types of VTOL propulsion technologies and analyze the advantages and disadvantages of each type. Such study will provide valuable insights for the drone community.

2. Analysis of VTOL Propulsion Systems

The analysis classifies each type of VTOL into 3 categories. This include: 1) TYPE1, which has a wing and a TILT-ROTOR, 2) TYPE 2, with no wings and similar to helicopters, and 3) TYPE 3 with wings and no tilting mechanism functions. The details are defined in **Table 1** [3]-[10].

Tables 2-5 show the specifications of VTOL drones in major countries. In fact, there are over 35 VTOL drones we have identified. Due to similarities, in this paper, we only show the representative types of VTOL drones. Those are illustrated in the tables below.

3. Analysis Contents

First, the percentage of VTOL types has been investigated, as shown in **Figure 1**. It shows that the Type 2 and Types 3 take the majority of the VTOL drones. VTOL with a tilt mechanism only takes about 18%. The reason can be conjectured that Type 1 drone can be unstable during the transit flight (*i.e.*, from hover to forward flight), and the tilting mechanism can add substantial weights as well as increase the complexity in the system. Due to these reasons, the Type 1 VTOL drones are comparatively limited. Type 2 and Type 3 VTOL drones are quite

Table 1. Classification of VTOL types.

	TYPE1	TYPE2	TYPE3
Wing	O	X	O
Tilt Rotor	O	X	X
VTOL	O	O	O

Table 2. There presentative VTOL drones in Korea and USA.

Contents	Picture	Picture
TYPE1		
Name	TR-100	Sky Prowler
Manufacturer	KARI	Krossblade Aerospace
Country	South Korea	USA
Length	5.0 m	0.5 m
Payload	100 kg	0.5 kg
Flying time	5 hrs	1 hrs
propellant	Gasoline	Motor
Max speed	500 km/h	100 km/h
TYPE1		
Name	JOBY S2	JOBY LOTUS
Manufacturer	JOBY AVIATION	JOBY AVIATION
Country	USA	USA
Length	N/A	N/A
Payload	176 kg	27 kg
Flying time	15 hrs	1 hrs
propellant	Gasoline electric hybrid	Gasoline electric hybrid
Max speed	200 km/h	185 km/h

Table 3. There presentative VTOL drones in Taiwan and Canada.

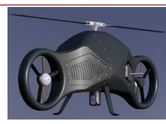
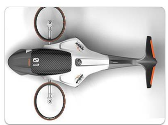
Contents	Picture	Picture
TYPE2		
Name	DTI RTN KSM 150	APID 60
Manufacturer	N/A	TOP Engineering
Location	Taiwan	Taiwan
Length	2.1 m	4.0 m
Payload	15 kg	55 kg
Flying time	2.5 hrs	5 hrs
propellant	Gasoline	Gasoline
Max speed	100 km/h	110 km/h
TYPE2		
Name	Navig 8 Gas	Navig 8 Electric
Manufacturer	4FRONT ROBOTICS	4FRONT ROBOTICS
Country	Canada	Canada
Length	3.1 m	1.64 m
Width	2.9 m	1.0 m
Payload	31 kg	4 kg
Flying time	2.5 hrs	1 hrs
propellant	Gasoline	MOTOR
Max speed	200 km/h	83 km/h

Table 4. There presentative VTOL drones in Japan and USA.

Contents	Picture	Picture
TYPE3		
Name	SR-1	ARCTURUS JUMP-20
Manufacturer	CQV	ARCTURUS
Country	Japan	USA
Length	1.7 m	2.9 m
Payload	0.7 kg	27 kg
Flying time	0.5 hrs	9 hrs
propellant	MOTOR	Gasoline
Max speed	55 km/h	133 km/h
TYPE3		
Name	V-Bat	Current MK1
Manufacturer	MARTIN UAV	Current MK1 (MK2)
Country	USA	USA
Length	2.4 m	2.0 m
Payload	2 kg	18.5 kg
Flying time	8 hrs	15 hrs
propellant	Gasoline	Gasoline
Max speed	350 km/h	148 km/h

similar in terms of numbers among the drone that we have investigated. Each type bears specific merits and also disadvantages, so each type takes about the same percentages. Second, we have analyzed each type according to the number of criteria investigated. The results are organized in Table 5 and Table 6. The table mainly shows the engine types (electric motors, gasoline powered, diesel, or hybrid engines), and flight durations (less than 2 hours of flying time, less than 4 hours, and over 4 hours).

By analyzing the content of the payload specification, the larger the size of the airframe, the more likely it was to see the airframe size increase. It appears to affect the flight time with drag on airframe, depending on whether or not the airframe is aerodynamically well balanced. Third, we have classified the VTOL drone in accordance with their size and payload. It appears that the size and payload will continue to increase in the future.

4. Conclusion

The analysis shows that the higher the payload, the bigger the size of the aircraft.

Table 5. Analysis of VTOL propellant technology.

VTOL TYPE	Model	Engine Type				Flying Time		
		Motor	Gasoline	Diesel	Hybrid	2 Hr↓	4 Hr↓	4Hr↑
TYPE 1	FE-Panther				O	-	-	-
	KUS-TR (TR-60)		O					O
	TR-100		O					O
	Sky Prowler	O				O		
	JOBY S2		O					O
	JOBY LOTUS				O	-	-	-
TYPE 2	Air Mule				O	-	-	-
	Airbus DS Tanan 300			O		-	-	-
	HEF32		O					O
	VSR700		O					O
	DTI RTN KSM 150		O				O	
	APID 60		O				O	
	Navig 8 Gas		O				O	
	Navig 8 Electric	O				O		
	DP-6XT WHISPER	O				O		
	UAV IT180-120		O			O		
	DP-12 RHINO		O				O	
	DP-14 HAWK		O				O	
TYPE 3	Aerosense	O				O		
	Wingtra	-	-	-	-	-	-	-
	VD 200	-	-	-	-		O	
	X-Plane		O			-	-	-
	SR-1	O				O		
	ARCTURUS JUMP-20		O					O
	V-Bat		O					O
	Current MK1 (MK2)		O					O
	FALCON-V		O					O
	PIGEON-V	O				O		
	JOUAV CW-20				O			O
	FOXY pro	O				O		

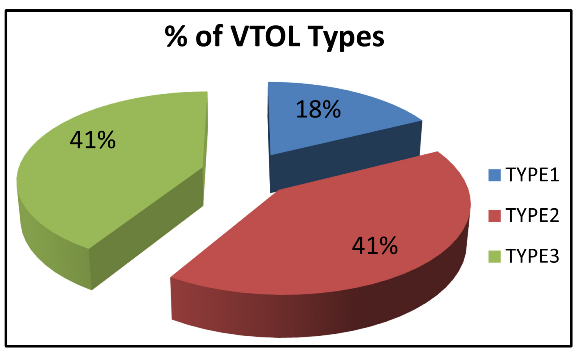


Figure 1. The percentage of VTOL types.

Table 6. Analysis of payload and wing span of VTOL drones.

VTOL TYPE	Model	Payload			Wing Span		
		10 Kg↓	20 Kg↓	20 Kg↑	2 m↓	5 m↓	5 m↑
TYPE1	FE-Panther	O				O	
	KUS-TR (TR-60)			O		O	
	TR-100			O			O
	Sky Prowler	O			O		
	JOBY S2			O			O
	JOBY LOTUS			O			O
TYPE2	Air Mule			O			O
	Airbus DS Tanan 300			O			O
	HEF 32	O				O	
	VSR 700			O			O
	DTI RTN KSM 150		O		O		
	APID 60			O		O	
	Navig 8 Gas			O		O	
	Navig8 Electric	O			O		
	DP-6XT WHISPER		O		O		
	DP-5X WASP			O	-	-	-
	UAV IT180-120	O			O		
	DP-12 RHINO			O	O		
	DP-14 HAWK			O		O	
TYPE3	Aerosense	O			O		
	Wingtra	O			-	-	-
	VD 200		O			O	
	X-Plane			O			O
	SR-1	O			O		
	ARCTURUS JUMP-20			O			O
	V-Bat	O				O	
	Current MK1 (MK2)		O			O	
	FALCON-V	O				O	
	PIGEON-V	O			O		
	JOUAV CW-20	O				O	
	FOXY pro	O				O	
	JOUAV CW-10	O				O	

It is more likely that a bigger air frame affects the flight time. For drones that use electric motors, the battery capacity is directly related to the flight time. However, a bigger battery size inversely affects the payload capacity. According to the analysis of three types, it appears that the fixed wing type VTOL drones with no tilting mechanism are getting more and more popular. It is due to the facts that this type of VTOL drone can provide a stable transit flight while reducing the complexity associated with tilting mechanism. So the drones can be built at a lower cost and a lot lighter. It is judged that the surge in global demand for a wide range of VTOL drone is expected, and a growing competition is expected around the world.

Acknowledgements

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