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Improvement of Auto-rotation Education through the Analysis of Helicopter Accidents – Focused on Model 500d

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Abstract

Background/Objectives: The purpose of the study is to suggest some measures for auto-rotation function education that helicopters can be safely land on the ground in the event of engine failure during the flight.

Methods/Statistical analysis: The data is based on an analysis of auto-rotation flight accidents that have occurred since 1982 with a focus on the single engine helicopter model 500d operated by Korea's Army Aviation. Statistical data analyzed the causes of accidents during the accident of Army Aviation are categorized as human, physical and environmental errors. In this study, only auto-rotation flight accidents were extracted and analyzed.

Findings: In this paper, we investigated and analyzed the auto-rotation flight accident of 500d helicopter and found that most of the accident causes were human error in the final landing stage and suggested the following four improvement measures. First, it is to strengthen theoretical education, such as calculating altitude-speed flow chart for auto-rotation flight, and fully acquire situation-specific flight technology to cope with external environment (airplane speed, wind, altitude, air density, temperature, etc.). Second, it is to establish an effective flight training system for VR (Virtual Reality) and AR (Augmented Reality) linked with the fourth industry. Third, it is to improve the overall flight education system through investment in equipment and facilities such as helicopter flight simulators. Finally, it is to do continuous efforts are made to improve pilot safety mind and comply with regulations and procedures to remove human error.

Improvements/Applications: The results of this study are expected to greatly contribute to the improvement of pilot training and flight training systems for aviation training institutions and flight units.

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1. Introduction

When the helicopter was first developed, it was mainly a single-engine helicopter, but twin-engine helicopters is developed to improve performance as time passed. Of the single-engine helicopters, the Model 500d is made of an egg-shaped fuselage to mitigate the impact of landing, and it is economical, but less secure. Therefore, in the event of an engine failure during flight, pilots must fully acquire auto-rotation flight techniques that lands safely on the ground using lifts and thrusts of blades that rotate automatically to preserve life and equipment through pre-trained flight.

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However, because it is not possible to artificially create an engine failure situation during an educational flight, instructor pilots are repeatedly training the procedure of landing on an auto-rotation flight by manually cutting the engine's power in half. Auto-rotation starts when the front of a helicopter momentarily rises for a few seconds due to a reduction in engine power or a failure phase during the flight, as shown in Figure 1. Recognizing this, the pilot lowers the collective pitch to confirm the landing zones. It means the entry stage of the auto-rotation flight. It will be dropped to a steep descent rate from then on, and pilots should maintain auto-rotation with normal control in these conditions. Pilots do deceleration operation through changing the attitude of the helicopter considering the external environment and the expected landing point at 50 to 100 feet of ground. Then, when the ground level is 10 to 15 feet, pilots pull the collective pitch to the upper pressure using wrist snap to stop the helicopter descent almost, and try to land with keeping the helicopter's attitude horizontally at 3 to 5 feet of ground. At this time, it is to make a smooth or slightly rougher cushion landing using the last remaining collective pitch of the helicopter [1, 2].

Otherwise, a terrible accident may occur. Single-engine helicopters are forced to operate with reduced engine power until they land, but twin-engine helicopters can use other engines to restore engine power before deceleration to safely land. In this paper, we analyze the case of the auto-rotating flight accident of the single engine helicopter model 500d, which is the most used in this paper, and present an improvement plan for the flight training system for accident prevention.

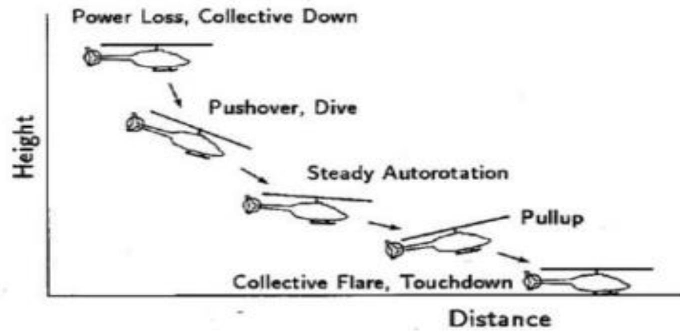

Figure 1. Auto-rotation Skill during landing [3]

2. Accidents Analysis of Helicopter Model 500d

The origin of the single-engine helicopter model 500d was the OH-6 helicopter developed by Hughes Aircraft Co. of the US in 1960. It has been deployed to the U.S. Army since 1966 and used efficiently during the Vietnam War. It was sold more than 1,400 units to nine countries. Since then, 4,700 units were sold by the name of Hughes 500 for business, and it was acquired by McDonald's Douglas Airlines in 1984 and are still operating in many countries around the world in the present [4]. Since it was introduced by the South Korean military in 1976, it has been mainly used by the Army and is being manufactured by a private airline company by switching to an unmanned helicopter.

Table 1 shows the cases of accident during auto-rotation flights by the South Korean Army Aviation since 1982.

Table 1: Case of Auto-rotation Accident of Model 500d [5]

Variable	Human factors	Physical factor	Environmental factors	Sum
Number of accidents	11	2	1	14
Accident rate	79%	14%	7%	100%

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As shown in Table 1, the biggest cause of the accident is human error during auto-rotation flight training. Most of these human factors accidents occurred during the landing phase. The main causes were a lack of corresponding ability of pilots to consider the conditions of the airfield and the external weather (wind, temperature, air density, etc.) and to identify the unique characteristics of each helicopter [6]. In particular, many accidents caused by the pilot's simple theoretical knowledge, experience and hubris due to the poor content of flight teaching materials and lack of flight theory training time. More fundamental problems, however, are insufficient flight education systems and pilot learning.

3. Improvement of Auto-rotation Education

As the result of analysis of the auto-rotation flight accident of the model 500d, the measures are suggested that the educational institution improve its flight education system and strengthen pilot learning. The following measures are to improve the flight training system and pilot learning and to 'zero' the probability of accidents.

First, pilots must fully learn how to calculate flow chart of height-velocity diagram and the contextual flight techniques to flexibly cope with changes in the external environment (airplane speed, wind, altitude, air density, temperature, etc.). Also they must understand the similarities or differences between actual flights clearly [7].

Second, it is also necessary to establish a training system using effective VR (virtual reality) and AR (augmented reality) in conjunction with the fourth industry [8]. Through this process, the educational institutions and their respective flight units should prepare a systematic flight education system, and the educational institutions should continuously update and disseminate textbooks that reflect the latest content, and secure effective educational conditions by increasing sufficient theoretical education and flight education time.

Third, educational institutions and each flight unit must enlarge the equipment and facilities called helicopter flight simulators to prepare basic conditions for safe flight by reflecting the mid- and long-term budget beforehand [9].

Fourth, it is necessary to focus on enhancing pilots' safety minds and complying with safety regulations and procedures to eliminate human error.

3.1 Enhancement of training in height-velocity flow calculations and situation-specific flight techniques

The operator manual called the pilot's Bible, is a textbook that records all instructions, information, and even related instructions and abnormalities that can occur before, during and after the flight. During the flight, the Pilot shall apply flow chart of height-velocity diagram calculation method as shown in Figure 2 with an understanding of the height-velocity to be avoided when landing on by auto-rotation flight in the event of an engine failure. In addition, the effects of the auto-rotation flight by applying additional external environmental factors such as wind direction, wind speed, and temperature should be applied to the actual auto-rotation flight through discussion.

For example, let's do flight training today. When starting auto-rotation flight training at 1,000 feet, the runway is 0 feet elevation and well-paved asphalt. And the outside temperature is good as 20℃, and the wind blows towards the runway at 10 knots. In this situation, let's calculate the height-velocity flow. At 1,000 feet, the speed is possible from zero knots, the helicopter speed is maintained at 90 knots before deceleration considering 10 knots of wind speed, the appropriate deceleration is 50 feet, and the amount of deceleration less than normal considering the

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external wind speed. The initial use of collective pitch is 10 feet, and after retaining the skid revel at 3 feet of ground, a smooth cushion landing can be made. Therefore, it is necessary to strengthen education on flow chart of height-velocity diagram calculation methods and contextual flight techniques [10, 11].

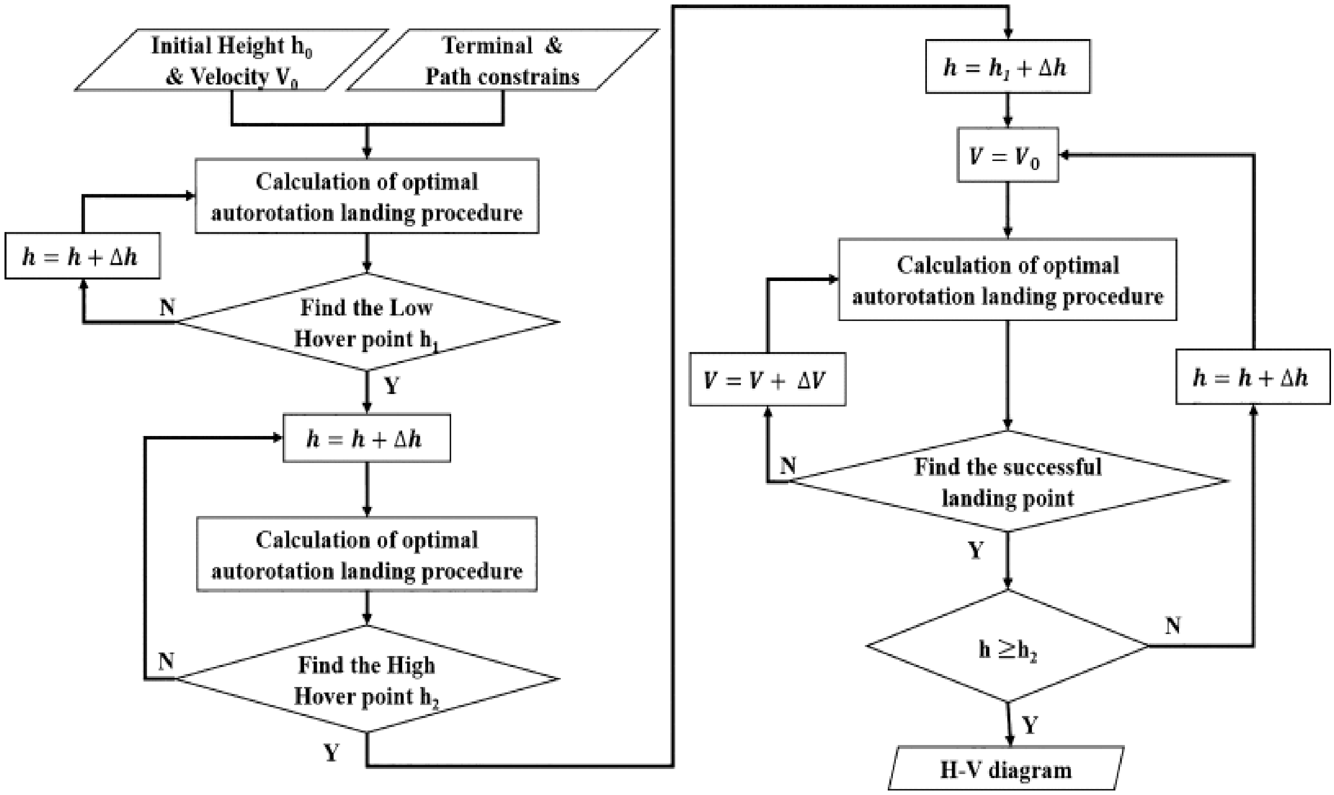

Figure 2. The flow of Height-velocity Diagram Calculation Method [7].

3.2. Application of VR and AR Training Systems

Using VR(Virtual Reality, Virtual Reality: Using computers and a variety of devices to experience something similar to the real world in five senses) and AR(Augmented Reality: Augmented: with a techniques that synthesizes virtual information or objects in real-world environments and provides more visual information) currently linked to the fourth industrial revolution, the flight education system of educational institutions and each flight unit needs to be improved with low cost and high efficiency. If enough simulated flight training is done through these equipment before actual flight, pilots' flying skills will be improved effectively, which in turn could result in safe flight.

In Figure 3 shows the U.S. Air Force currently educating pilots in the pilot introductory process using a low-cost simulation system that combines VR Gear or VR Head Mounted Display (HMD: Wear it like glasses, which are similar to the existing simulator training system, but can simplify mechanical equipment and configuration while increasing the effectiveness of training) into a commercial PC-based system [8]. The rapid spread of the VR·AR training system around the U.S. and other advanced countries is due to the fact that realistically acquires information faster through visual information. It is also easily accessible to the new generation of young people, adaptable to rapid changes, and can be built at a relatively low cost, although there will be cost differences depending on the training system. Using smart phones and various smart devices, it

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is characterized by combining various information into virtual reality and images that are taken with a full virtual world. These VR·AR training systems can be more safely implemented in virtual training situations that feel real, and will help pilots maintain a horizontal posture through calculating the altitude of deceleration and the degree of application of the initial pitch with linking the procedural training and visual information. It can also train the basic or tactical flights and night flights of student pilots indirectly. Especially, it is usefully used when flight is not possible due to bad weather. Therefore, VR·AR training systems in educational institutions and flight units are very effective to prevent safety accidents and reduce education budget and actual training flight time.

However, even if the VR·AR training system is optimized, the technical limitations, and basic features of the human brain cannot be overcome 100%. Also, it has the disadvantages that are not as effective as controlling using the entire body through actual flight. Therefore, VR·AR technology can produce the best efficient results when working together with existing flight training systems as one of methods for improving education and training for helping pilots.

Figure 3. U.S. Air Force VR·AR Simulation Training System [8]

3.3. Establishing a helicopter flight simulator

The helicopter flight simulator is a collection of hardware and software, including motion, acoustic information, visual information, location information, a cockpit and flight dynamics model information [9]. Building a flight education system through these helicopter flight simulators will greatly make the auto-rotation flight training of single engine helicopters to zero the accident rate, and will greatly help improve pilots' skills [12]. Therefore, educational institutions and their flight units need to introduce helicopter flight simulators through reflecting mid- and long-term budgets in advance to enhance the effectiveness of education by combining auto-rotation simulation training and actual flight. Table 2 outlines the basic models and deployment status and technology levels of major simulators developed in Korea, Europe, and the United States.

Table 2: Types of Helicopter Simulator [9]

Name	Image	Country (Company)	Model	Control function	FAA Certification	Location (Year)
KA-32T		Korea (KARI)	Based on GENHEL (using flight lab modeling tool)	Attitude Hold Altitude Hold Hover Hold Integrated Flight System (IFS)	Level C (unofficial)	KARI (2007)

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KUH-1		Korea (KAI)	Based on GENHEL (including Glauert's flow model, flapping effect, ground effect, vibration effect)	Roll/Pitch/Yaw SAS, Roll/Pitch/Yaw Attitude Hold	Level 7 Level D	Nonsan, Korea (2012)
MUH-1						Pohang Korea (2019)
EC135		Europe (Entrol)	Based on GENHEL, (including flapping effect, ground effect, dynamic inflow model)	Yaw/Roll SAS	Level 6 Level C	Kobe, Japan (2014)
AW139		Europe (Thales)	Based on ARMCOP, (including flapping effect, ground effect)	SAS, Attitude Hold in pitch /roll	Level 7 Level D	Brisbane Airport, Australia (2016)
AW109		USA (CAE)	Based on ARMCOP, (including flapping effect, ground effect)	SAS, Attitude Hold in pitch /roll	Level 6 Level D	Sesto Calende, Italy(2001)
AW139						Morristown, USA (2008)
AS350 B2		USA (FRASCA)	Based on ARMCOP, (including Flapping effect, Ground effect, vibration effect)	SAS, Attitude Hold Altitude Hold Heading Hold	Level 6 Level D	China (2014)
Bell-206L					Level 7 -	Air Evac Life team, Missouri, USA (2015)

3.4. Improving the safety mindset of pilots

Because most of the auto-rotation flight accidents is caused by human errors, pilots should have a mental attitude that will not relax until the final landing. To ensure safe flight, it is necessary to provide continuous safety mind training and meditation opportunities for pilots and to establish a thorough inspection system for compliance with safety regulations and procedures. In addition, a system should be established to regularly check pilots' mental health and psychological counseling every year to enhance safety awareness through necessary prescriptions.

4. Conclusion

A single-engine helicopter must land on an auto-rotation flight to minimize loss of life and equipment if the engine fails or power decreases during the flight. In this paper, we investigated and analyzed the auto-rotation flight accident of 500d helicopter and found that most of the accident causes were human error in the final landing stage and suggested the following four

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improvement measures. First, it is to strengthen theoretical education, such as calculating altitude-speed flow chart for auto-rotation flight, and fully acquire situation-specific flight technology to cope with external environment (airplane speed, wind, altitude, air density, temperature, etc.). Second, it is to establish an effective flight training system for VR (Virtual Reality) and AR (Augmented Reality) linked with the fourth industry. Third, it is to improve the overall flight education system through investment in equipment and facilities such as helicopter flight simulators. Finally, it is to do continuous efforts are made to improve pilot safety mind and comply with regulations and procedures to remove human error. The results of this study are expected to greatly contribute to the improvement of pilot training and flight training systems for aviation training institutions and flight units. In the future, detailed action plans for doing each improvement plan and their effect analysis will be required.

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