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Research and implementation of visual helicopter coning angle measurement system

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ABSTRACT

A visual helicopter coning angle measurement method is presented in this paper. First, a reflective target is pasted onto the helicopter rotor tip; second, a high-speed industrial camera and LED strobe light are used to obtain grayscale images of each blade's reflective target when the rotor is rotating; Third, target grayscale images are processed using the Otsu threshold segmentation algorithm to obtain binarized images. Next, the eigenvalues of the images are obtained using Sobel operator edge detection method, so the height difference of the reflective target and the helicopter coning angle can be calculated. A prototype measurement system is designed to prove the feasibility and scientific validity of the method. Experimental results show that the system is easy to operate, and the measurement accuracy is approximately 0.5 mm.

1. Introduction

The rotor system is the most important part of a helicopter and undertakes three types of functions: propulsion, weight loading and control. The helicopter flight quality is closely related to the rotor system, which is composed of a rotor shaft, rotor blades and a helicopter hub [1].

The blade will lift up slightly when the helicopter hub rotates at a high speed, adopting a shape similar to an inverted cone, with the blades track at the bottom of the cone. Fig. 1 shows schematic diagram of the blades track.

The blades should rotate on the same cone surface when the helicopter hub rotation speed is fixed, that is, θ is fixed. One of the most important parameters of the rotor blade is the helicopter coning angle [2,3]. The helicopter coning angle is not easy to measure, and the accuracy of the data is low, because a helicopter rotor operates in a complex environment, and the noise level is high [4]. Currently, the main methods for measuring the helicopter coning angle are as follows:

1. The paper tube method. This method, which has the advantage of a simple measurement principle and low cost, has been used around the world since 1950. However, this method can only be applied to measurements on the ground. Moreover, the measurement results cannot be saved, and the measurement accuracy is approximately 6 mm. A schematic diagram of the measurement principle is shown in Fig. 2.
2. The universal track device (UTD). The UTD has a photoelectric sensor that can receive a pulse signal when the

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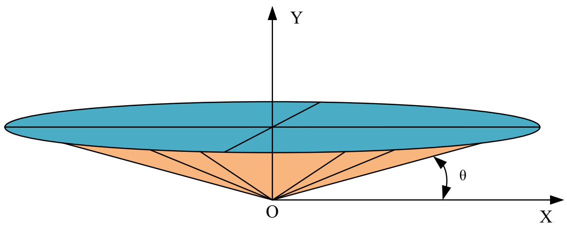

Fig. 1. Schematic diagram of the helicopter blades track.

blade blocks a photoelectric beam. The embedded computer can determine the blade trajectory based on the time intervals of the signals. The measurement accuracy is approximately 2 mm. This method is the most widely used around the world [5]. A schematic diagram of the UTD measurement principle is shown in Fig. 3.

3. The Rotortuner Line Scan camera. The representative measurement equipment is RT2000, which is developed by Helitune. This method has the advantages of simple operation and fast measurement speed, and the consistent coning angle data and optimum information on each blade can be provided using an intelligent blade recognition algorithm and data tracked at the blade tip. However, the measurement accuracy is approximately 2 mm, and the measurement results depend on environment conditions, such as low light and blue sky conditions. A schematic diagram of the measurement principle is shown in Fig. 4.

Another helicopter rotor pyramid angle measurement method is the image recognition technique [6–9], the measuring accuracy of which is approximately 1.5 mm.

In this paper, a new helicopter coning angle measurement method is studied. First, grayscale images of a reflective target are obtained using an industrial high-speed video camera. Second, using the Otsu threshold segmentation algorithm to process the grayscale images, the binary images are obtained. Third, the Sobel operator is used to obtain the image edges and eigenvalues. Finally, the target height differences for each blade are obtained, and the helicopter coning angle value can be calculated. Helicopters with up to 6 blades with rotation speeds of between 100 r/min and 400 r/min can be measured using the system. The measurement accuracy is approximately 0.5 mm.

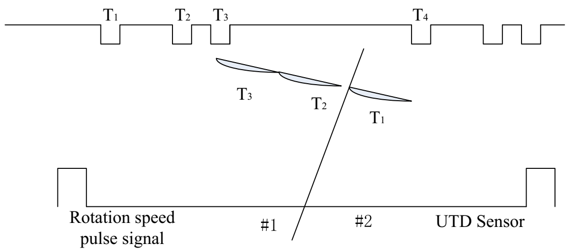

Fig. 3. Schematic diagram of the UTD measurement method.

2. Measurement system description and measurement principle

2.1. Measurement system description

The system mainly consists of a video capture unit and a PC104 mini-computer data processing unit for rotor speed measurement and signal conditioning. Fig. 5 shows the system block diagram, and Fig. 6 shows a photograph of the system.

2.2. Measurement principle

The magnetic speed sensor is mounted on the swashplate. Photographs of the magnetic speed sensor and its mounting position are shown in Fig. 7. The magnetic sensor is a passive device and has the advantage of good anti-jamming capability and reliability.

A single reflective target is pasted onto each blade tip, and a photograph of a target is shown in Fig. 8. The rectangular reflective target is pasted onto a standard blade, and the circular reflective target is pasted onto the measured blade.

The spike pulse signal is generated by a magnetic speed sensor when the rotor completes one rotation cycle, and then the signal is filtered, shaped and amplified by the signal conditioning circuit. Assuming the type of helicopter under study has three blades, the original signal and processed target signal waveforms are shown in Fig. 9.

T denotes the period of helicopter rotor rotation. B_1 denotes the position of standard blade, B_2 and B_3 denote the positions of the measured blades, and t denotes the width of the trigger pulse, which determines the camera

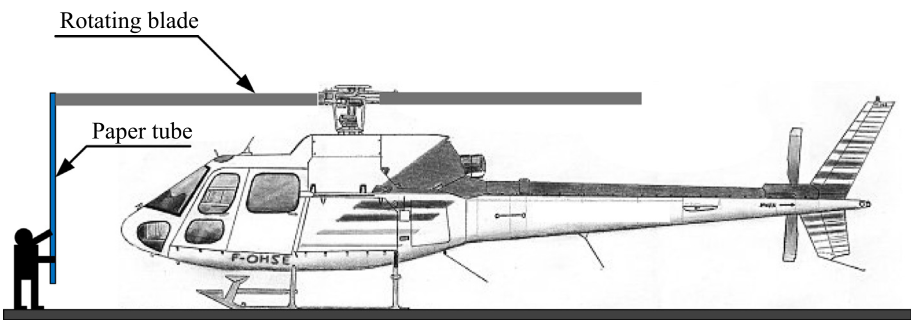

Fig. 2. Schematic diagram of the paper tube measurement method.