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An Investigation in Non Destructive Testing using Drones on Existing Buildings

K.V.Ganesh[1], M.Sri Priya[2]
B. Tech Student[1], M. Tech, (Structural Engineering)[2]
Department of Civil Engineering
Jawaharlal Nehru technological university, Ananatapur, A.P, India

Abstract:
Non destructive testing has achieved an important place in the Quality Assurance of hardened concrete and the evaluation of existing concrete structure with regard to their strength & durability. Ultrasonic scanning is a recognized non-destructive evaluation test to qualitatively asses the homogeneity and integrity of concrete. This project entailed design and testing of an indoor quadrotor UAV capable of autonomous take-off, landing, and path finding for ultrasonic pulse velocity. The propulsion system produces 1500g of thrust at 46% throttle using 7" propellers, minimizing craft size, but allowing for sufficient payload to carry a LIDAR, a CMOS camera, and rangefinders and ultrasonic pulse velocity equipment. These sensors are interfaced to an Overo processor, which sends high-level commands to a low-level flight controller, the HoverflyPro. Flight tests were conducted which demonstrated flight control and sensor operation for ultra sonic pulse velocity testing .This simplifies the design and maintenance of the vehicle. This reduces the damage caused should the rotors hit anything.

Keywords: NDT, Drone, ultra sonic velocity, Quad Copter. Etc.,

I. INTRODUCTION

Non-destructive testing is defined to evaluating the continuity, integrity, security or some physical properties of materials, components or structures via a variety of physical principles without compromising performance of object to be tested. Purpose is to detect whether material or structure is flawed, or tests the defectives' shape, orientation, size, distribution, etc., and judges the contents of materials. Nowadays, widely used non-destructive testing methods of metal fatigue detection include ray inspection, ultrasonic and acoustic emission detection, electrical and electromagnetic detection. Modern NDT techniques also include computer data and image processing, image recognition and synthesis, etc. Some presently available NDT with drone quad copter techniques are introduced in this paper.

II. NON DESTRUCTIVE TESTING TECHNIQUES

Nondestructive testing techniques are used since the evolution of mankind and are continuously improvised with time and technology. These techniques are useful in quality control and maintenance. The nondestructive techniques that are applied at various manufacturing stages of a „low pressure heater "The strength tests, regardless of the type, are excellent for determining the criteria of quality & quality control during construction, but they leave a lot to be desired. The main disadvantage of such tests are delay in obtaining test results, the fact that the test specimen may not be truly representative of the concrete in a structure, the necessity of stressing the test specimen to failure, the lack of reproducibility in the test results and the relativity high cost of testing & wastage of concrete in form of cubes. Nondestructive methods of testing cannot be expected to yield absolute value of strength. These methods, therefore, attempt to measure some other property of concrete from which an estimate on its strength, its durability and its elastic parameters is obtained. Such properties of concrete are its hardness, rebound number and its ability to allow ultrasonic pulse velocity to propagate through it. The electrical properties of the concrete, allow us to estimate its moisture content, density, thickness and its cement content. Based on above, various nondestructive methods of testing concrete have been developed. Popular NDT Tests for Concrete Used in field are:

- Rebound Hammer Test- RH Test
- Ultrasonic Pulse Velocity- UPV Test
- Combined Method UPV & RH Test
- Core Extraction for Compressive Strength Test
- Ingredient Analysis of Concrete Core
- Concrete Cover Measurement by Laser Based Instrument

III. DRONE-QUAD COPTER

A quad copter is a flying vehicle possessing 4 identical rotors, evenly spaced around the central fuselage. First, quadrotors do not require mechanical linkages to vary the rotor blade pitch angle as they spin. Second, the use of four rotors allows each individual rotor to have a smaller diameter than the equivalent helicopter rotor, allowing them to possess less kinetic energy during flight.

Figure.1. Drone quad copter

For small-scale UAVs, this makes the vehicles safer for close interaction. Some small-scale quad rotors have frames that enclose the rotors, permitting flights through more challenging environments, with lower risk of damaging the vehicle or its surroundings.

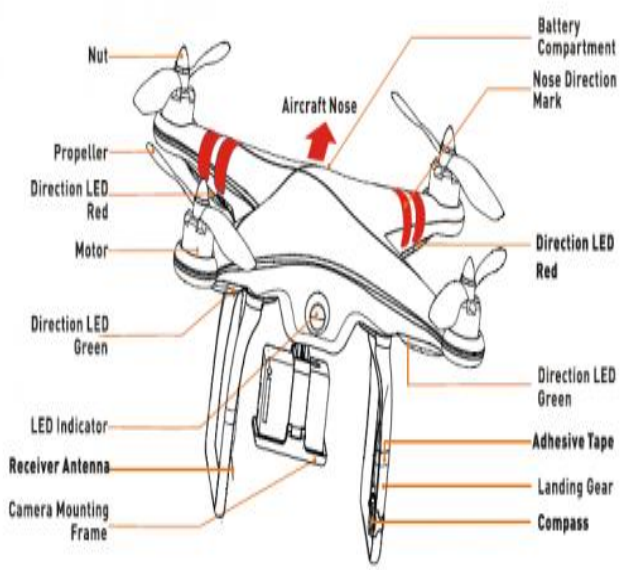


Figure.2. Components of quad copter

Electronic Speed Controller (ESC): Regulates power to the motor according to the input throttle level. It also provides +5V power for the flight electronics

RC Receiver: A (usually 2.4 GHz) RC radio receiver on the quadcopter that receives commands from the RC transmitter on the ground. One way link

Telemetry Link: A (usually 915 MHz or 433 MHz) bidirectional link between the flight controller and ground station. Provides current status to the ground station and accepts flight commands to the quadcopter.

RC Transmitter: A (usually 2.4 GHz) RC radio transmitter used by the pilot to direct the quadcopter's direction and position.

Hub: The central fuselage of the quadcopter. Contains the flight electronics and battery

Arm: The beam that each of the motors sits on.

IV.EXPERIMENTAL METHODOLOGY

1. ULTRASONIC PULSE VELOCITY TEST

Ultrasonic scanning is a recognized non-destructive evaluation test to qualitatively asses the homogeneity and integrity of concrete.

i) Preparing for use: Before switching on the 'V' meter, the transducers should be connected to the sockets marked "TRAN" and " REC". The 'V' meter may be operated with either:
a) the internal battery,
b) An external battery or
c) The A.C line

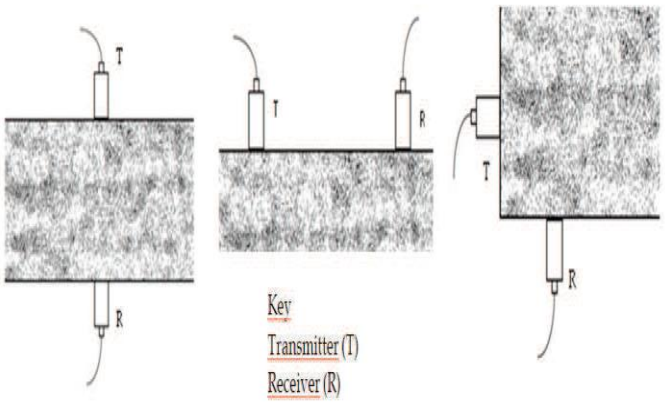
ii) Set reference: A reference bar is provided to check the instrument zero. The pulse time for the bar is engraved on it. Apply a smear of grease to the transducer faces before placing it on the opposite ends of the bar. Adjust the 'SET REF' control until the reference bar transit time is obtained on the instrument read-out.

iii) Range selection: For maximum accuracy, it is recommended that the 0.1 microsecond range be selected for path length up to 400mm.

iv) Pulse velocity: Having determined the most suitable test points on the material to be tested, make careful measurement of the path length 'L'. Apply couplant to the surfaces of the transducers and press it hard onto the surface of the material. Do not move the transducers while a reading is being taken, as this can generate noise signals and errors in measurements. Continue holding the transducers onto the surface of the material until a consistent reading appears on the display, which is the time in microsecond for the ultrasonic pulse to travel the distance 'L'. The mean value of the display readings should be taken when the unit's digit hunts between two values.

Pulse velocity = (Path length/Travel time)

v) Separation of transducer leads: It is advisable to prevent the two transducer leads from coming into close contact with each other when the transit time measurements are being taken. If this is not done, the receiver lead might pick-up unwanted signals from the transmitter lead and this would result in an incorrect display of the transit time. The direction in which the maximum energy is propagated is at right angles to the face of the transmitting transducer; however, it is possible to detect pulses travelling through concrete in some other direction. In other words it is possible, to make measurements of pulse velocity (BS 12504-4, 2004) by placing the two transducers on either:
a) Opposite faces - direct transmission (Figure 1a),
b) Adjacent faces - semi-direct transmission (Figure 1b);
c) The same face - indirect or surface transmission (Figure 1c).



(a) Direct Transmission (b) Indirect or surface Transmission (c) Semi-direct Transmission

Figure.3. Methods of propagation and receiving ultrasonic pulses

Direct transmission is the most sensitive, and indirect transmission the least sensitive. Indirect transmission should be used when only one face of the concrete is accessible, when the depth of a surface defect or crack is to be determined or when the quality of the surface concrete relative to the overall quality is of interest. The velocity, v, is calculated from the distance, between the two transducers and the electronically measured transit time, t, of the Pulse as:

$$V = \frac{L}{t} \text{ (m/s)}$$

Figure.4. Ultra pulse velocity instrument

Table.1. Ultra sonic pulse velocity test grading of values

S.No	Pulse velocity(Km/Sec)	Concrete Quality Grading
1	Above 4.5	Excellent
2	3.5 to 4.5	Good
3	3.0 to 3.5	Medium
4	Below 3.0	Doubtful

2. DRONE QUAD COPTER:

The craft propels itself with four propellers aligned in a plane. Each propeller is driven by a brushless DC motor, which is controlled with an electronic speed controller (ESC). Each of the four propeller-motor systems has its own Li-Po battery. The ESCs are driven by a low-level flight controller called the HoverflyPro. The HoverflyPro receives autonomous commands from the Overo processor. The primary autonomous feature that was designed is an altitude control loop, which would allow for autonomous take off and landing of the craft. This control loop relies on data from an ultrasound and an IR sensor. There is a fail-safe circuit that allows for a manual switch out of autonomous mode. An I2C interface and a UART-to-RS232 interface were implemented to allow for the addition of the nano IMU and a Hokuyo LIDAR. These sensors can be used to implement higher level control algorithms and eventually mapping capabilities ideal for a search and rescue robot. The propulsion system will carry a payload of 1500g for about 10 minutes. The maximum additional carrying capacity is approximately 900g. Design predictions were compared with simulations and with test data. We found that our simulation methods were accurate to within 10 percent of the test data. The overall efficiency is approximately 34% for the whole system, 80% for the motors, 47% for the propellers, and 90% for the speed controllers. The craft achieves hover at about 8A current draw per motor.

V. RESULT AND DISCUSSION

The table gives the result of ultra-pulse velocity test on concrete cube [M_{60}] at 28days curing period. All the samples tested for ultrasonic pulse velocity ranges between 3750 m/s to 4290m/s which can be termed as very good concrete.

High Strength Fiber Reinforced Concrete (HSFRC)

Table.2.Results of Ultra Sonic Pulse Velocity Test (HSFRC)

S.No	Case S-SILICA FUME F-FLY ASH	path time (µ-sec)	Average pulse velocity (km/sec)	quality of concrete
1	Controlled mix	34.63	4.33	Good
2	S10F10	35.80	4.19	Good
3	S10F20	35	4.28	Good
4	S10F30	38.7	3.87	Good
5	S15F10	39.7	3.77	Good
6	S15F20	35.8	4.18	Good
7	S15F30	36.33	4.15	Good

VI.CONCLUSIONS:

The pulse velocity method has been applied successfully in the laboratory as well as in the field. It can be used for quality control, as well as for the analysis of deterioration. The applications of the pulse velocity method on a concrete structure are Estimation of Strength of Concrete, Establishing Homogeneity of Concrete, Studies on the Hydration of Cement, and Studies on Durability of Concrete, Measurement of Surface Crack Depth, and Determination of Dynamic Modulus of Elasticity. We have demonstrated that with a carefully designed power train a quad rotor can have enough payload capacity and flight time in a small enough package to be useful for urban search and rescue, and that our design would be available at a price-point acceptable to most search and rescue task forces. However, using easily available and NDT ultrasonic pulse machine in the airframe, and focusing on the design of an optimal power train would yield a much more attractive package which could be equipped to perform similar capabilities.

VII.FURTHER SCOPE:

The logical next step is to continue to add functionality to the flight features of the craft. It was designed such that it would be capable of piloting itself autonomously in and out of buildings, and while inside be able to pass through doors and generate a real-time map to conduct seismic tests in existing buildings using drones with lab equipment.

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IX. AUTHOR PROFILE

M.sri priya, B.Tech in Civil Engineering and M.tech in Structural Engineering Jawaharlal Institute of Technology Anantapuramu

K.V.Ganesh, B.Tech in Civil Engineering, Jawaharlal Institute of Technology Anantapuramu