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Drone impact on human beings : Experimental investigation with sUAS

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Beyond some application related to military and civilian operations [1], the major part of the financial market is related to the use of unmanned aircraft systems (UASs) by casual customers without specific training. This requires to solve a technological and legislative challenge to ensure the safety of the population regarding the use of an aeronautical system potentially near buildings and apt to fall over people on ground. For almost 10 years and even more recently, regulatory institutions at the global scale have performed a significant work to classify UAS regarding their lethal potential in a case of an impact with people on the ground [2, 3, 4, 5]. Nevertheless, the establishment of a consensus remains a challenging task given the lack of specific and exploitable experimental data on the problematic. Hence, the purpose of the study is twofold. It first aims at providing qualitative findings on the legal and scientific framework regarding the assessment of lethal injury thresholds related to UAS impacts on human-beings. Based on this framework, the study then relies on an experimental investigation. A dedicated protocol is developed in order to minimize the sources of discrepancy previously identified and in order to conduct representative impact test cases using commercially-availables UAS. The range of drones masses considered in this study is about 900 grams with respect to the open category defined by EASA.

Very few studies are dedicated to assessing the severity of an UAS impact on human beings. There are studies performed with commercially available drones and those using drones manufactured specifically for the study. The tests conducted by the NIAR rely on the use of a DJI Phantom 3 (1.2 kg) and aim at analyzing three kinds of skull impact configurations [6]. By varying the height and the speed of UAS impact, the different tests are analyzed using bio-mechanical criteria such as head injury criterion (HIC) and abbreviated injury scale (AIS). Other types of measured quantities are also considered such as the impact energy and the head acceleration magnitude. On one hand, this study highlights the need for repeatable experimental testing and accurate measurements. On the other hand, it emphasizes the difficulty of achieving a unanimous conclusion on the lethal potential of the considered drone given the inconsistent conclusions drawn from the different criteria. The study conducted at the Virginia Polytechnic Institute, which also investigates the impact of a Phantom 3, concluded that this type of UAS is not lethal both for frontal and vertex skull impacts [7]. Nevertheless, none of the tests were developed to control the area of impact on the test dummy. Beyond theses studies conducted with commercial UASs, the study conducted at the Politecnico di Torino institute is focused on home-made UASs impacts [8]. The quadri-rotor configuration is relatively simple and uses steel for the body and rotor supports while the arms are made of carbon tubes. Under 5 configurations of impact, the study concludes that even for a UAS mass of less than 2 kg, very serious injuries could be obtained. Nevertheless, results can be questioned due to the fact that only one test was performed for each configuration moreover with a really simple design for the home made UAS. The study conducted at the Air Traffic Research Institute of Singapore aims at characterizing a threshold which combines altitude of flight and mass [9]. According to the authors, a lethal impact could occur from a height of

about 60 meters with an UAS of 250 grams and from 7.60 meters with an UAS of 1.2 kilogram. Again, the simplified design of the UAS considered for the experimental investigation can be criticized. The experimental investigation performed in this study relies on the use of two commercially available UASs. The DJI Mavic pro with a mass of 800 grams and the Parrot Anafi with a mass of 400 grams are considered. Both UASs are accelerated and guided by means of an hydraulic jack able to reach a maximum speed of 16 m/s. The speed is defined to be consistent with the typical terminal velocity of this kind of UAS. Three configurations of impact and three tests of repeatability for each configuration and each UAS are performed. Specific setups are developed in order to ensure a coaxial impact between the center of gravity of the test dummy and the one of the UAS. The objective is to obtain an impact configuration closed to the worst case scenario. The head and the neck of the dummy are instrumented by means of triaxial accelerometers. A set of a 2D calibrated photometric measurement allows to evaluate the speed and to observed the impact of the UAS on the dummy's head. As a first step, the analysis is performed by measuring forces, resultant head acceleration and HIC. Other types of indicators may be considered secondly since an evaluation of the impact area is also proposed in these tests. The experimental investigation is currently performed and the results will be presented during the conference.

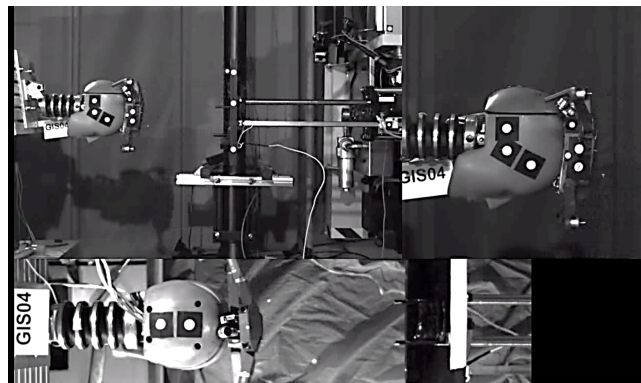


Fig. 1. Vertex impact with DJI Mavic pro

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