Investigation of impacts between unmanned aerial vehicle motors and various targets

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Abstract:

Small unmanned aerial vehicles (sUAV) are an increasing threat for manned aviation. The total amount of unmanned aerial vehicles (UAV) within the airspace grows. UAVs are taking over an increasing number of tasks. Those reach from parcel delivery to traffic monitoring, photography and further leisure activities. This results in an enhanced probability for airborne collisions, thereby UAVs are a safety concern for manned aviation [1, 2]. Previous studies show that particularly heavy and dense components of such sUAVs can severely damage aircraft structures [3]. Therefore, this paper analyses the impact behavior of motors from a DJI Phantom 4 with various targets. In particular, the impact on rigid targets and aluminum Al2024-T3 specimens is studied.

We follow a stepwise structure and begin with quasi-static compression tests of the motors. Then we study high velocity impacts (HVI) on rigid target structures. Finally, HVI tests on deformable aluminum Al2024-T3 targets are investigated. A gas cannon is used to carry out the high velocity impact tests. FE models of the motor and the targets are developed for the explicit solver Radioss. The model of the motor is validated against the test data. Based on the force-deflection curves from the compression tests we can neglect the position of the inner motor reinforcements. The analysis of the rigid wall investigations shows, that the impact the motor forms two load plateaus. The first plateau is about 40% of the maximum force of the second plateau. We see that a single motor penetrates the aluminum Al2024-T3 samples at 139.3 m/s impact velocity, but does not perforate it. The impact produces a petaling damage. The FE results show that for this speed, depending on the impact angle, perforation of the target may occur (see Figure 1).

We found that impacts with a low energy (up to 42 J) are comparable to quasi-static test results. Higher impact energies lead to larger deviations in the force-deflection curves between quasi-static and impact tests. A single motor of a drone is able to penetrate an Al2024-T3 structure at a speed of 139.3 m/s. Perforation of the target depends on the inclination of the motor projectile. From an inclination of 22.5°, our simulations show a perforation of the target structure. This opens up the possibility of reducing the damage by adjusting the drone's flight attitude before an unavoidable mid-air collision. Results from this paper enable first estimations of possible damage and threat scenarios by investigation of deformable targets for HVI. Furthermore, we gain an in-depth knowledge of damage behavior of sUAV motors under different velocity regimes. In comparison to the existing literature, we have created a data basis for impact tests of sUAV motors. The data from those test series may be used for further investigations as well as validations of impact simulations of sUAV engines.

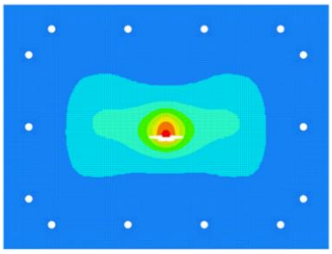
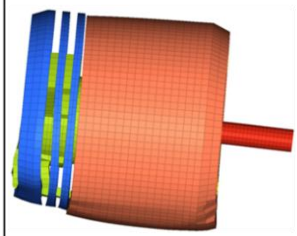
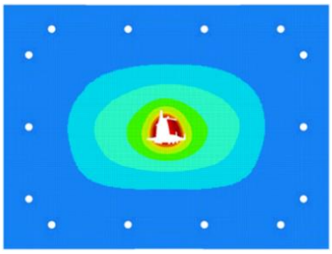
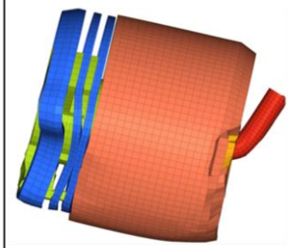
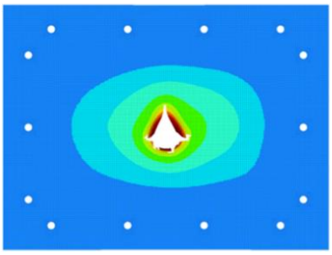
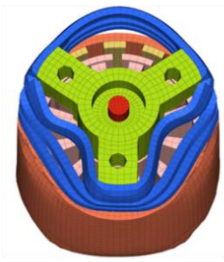
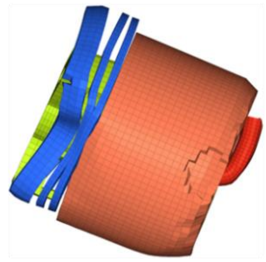
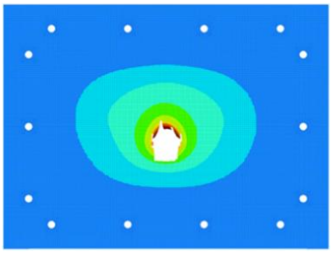
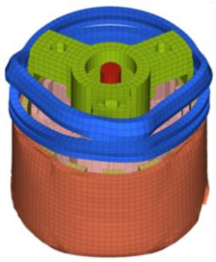
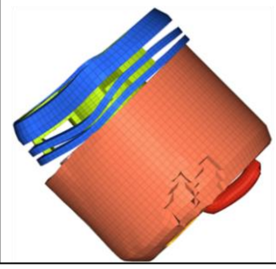
α [°]	Penetration	Al2024-T3 Front	Motor	
0°	No			
11.25	No			
22.50	Yes			
45.00	Yes			

Figure 1: Damage of target and projectile for various flight angles

References

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