1. Context

Gimball is a drone developed by Flyability SA. This drone has the specificity to be tolerant to in-flight collision, and to remain stable after contacts. For this, the robot is protected by a rotating cage, which has to sustain relatively high impact energies and to be as light as possible.

2. Aims

This project mainly focused on the connectors of the Gimball’s cage. The main aims were to:
- Improve and develop the cage manufacturing for short-, mid-, and long-term approaches
- Test full cage structures and improve their impact properties

3. Processing and Adhesion

Industrialisation is planned in three main stages:

1. Adhesive bonding between the carbon rods and the 3D-printed connectors. 8 adhesive resins:
   - 2 Epoxies, 3 Cyanoacrylates, 2 Methacrylates, 1 Polyurethane
2. Casting of a thermoset resin in a mould over the placed carbon rods → direct production of sub-elements
3. Thermo-moulding of a thermoplastic polymer over the placed carbon rods → direct production of sub-elements

Material Selection

Thermoset: Polyurethane (PU)
Thermoplastics: Thermoplastic Polyurethane Elastomer (TPU, Elastollan), Thermoplastic Copolyether Ester Elastomer (Hytrex) and Polyamide 12 (PA)

Results

Adhesives: Cyanoacrylates seem to be the best promising candidate: good adhesion and easy/fast to implement

4. Impact Properties

Method

Drop Setup:
- Accelerometers and gyroscopes
- Variable height
- Variable impact locations
- On a flat ground or on a corner
- Hanged with an electromagnet and a metallic tether

Results

Initial Cage: too soft, glue failures and pentagon reversal.

Energy-Displacement: Initial cage. The black line represents the zone to protect

Cage geometries:
- Geodesic 2v: better transmission of forces to the whole cage, due to neighbouring connectors reaching the obstacle.
- Neighbouring connectors reaching the obstacle

Rigidity of connectors: High rigidity → avoid pentagon reversal and decrease deformation

Geometry of connectors: flexibility needed between the 3-arms connectors for preventing pentagon reversal. Extreme rigidity of the connector also prevent it.

Connectors geometry tested

Final Hybrid cage: soft 5-arms connectors, rigid 3-arms connectors. Failures: zip ties connecting the sub-elements. Better than initial cage, but too much deformation at 4f. Could maybe be improved by using wider zip ties.

5. Conclusion

- Cyanoacrylate were the best adhesives, with an easier and faster process for a final good adhesion
- Casting and thermo-moulding presented higher shear strength than adhesive bonding
- Final cage: possibility to reinforce the zips → it lead to connector failure, change the rigid thermoplastic for a rigid elastomer, such as a TPC (shore D70)
- Produce cast/thermo-moulded pentagons with the chosen materials, in order to test their impact properties
- Tune the rigidity of the connectors and the dampers to attain the desired properties
- Perform fatigue and repeatability tests

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