FACULTY OF ENGINEERING AND ARCHITECTURE

OVERLOAD CLUTCH WITH INTEGRATED TORQUE SENSING FOR HYBRID INDUSTRIAL COBOTS

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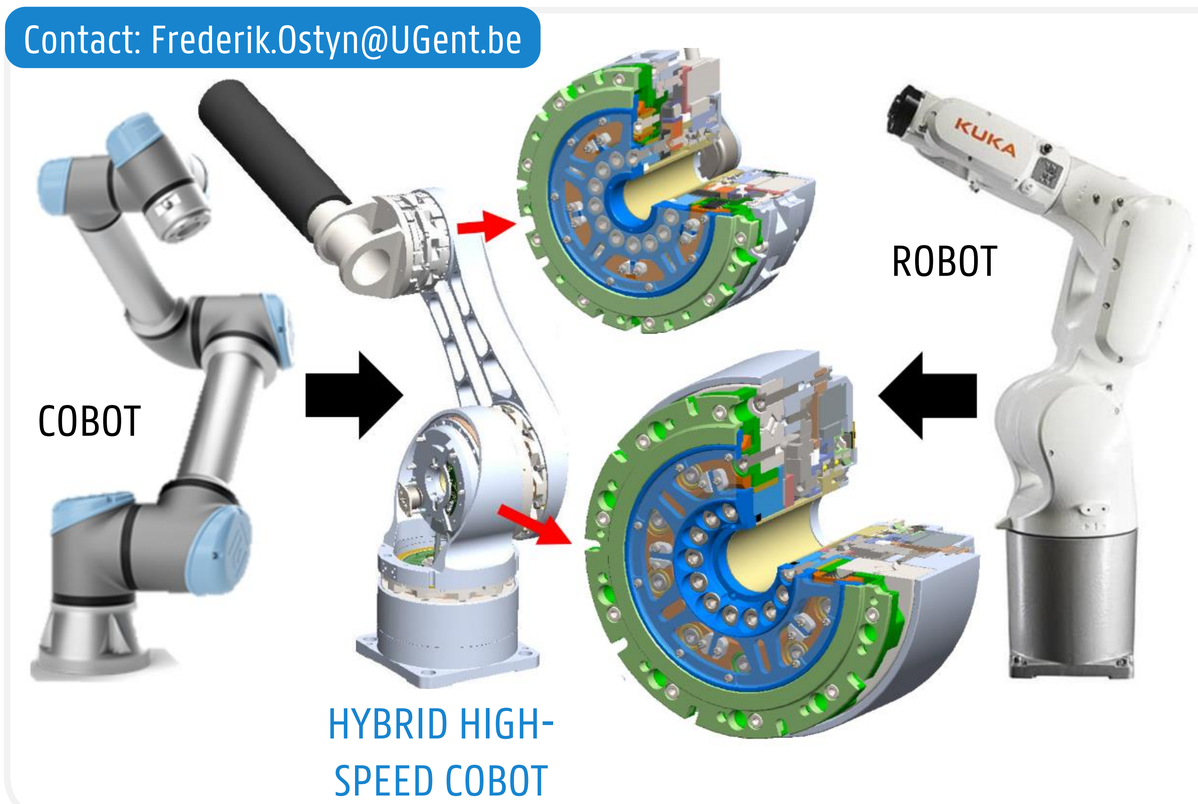


WHY? COLLISIONS @ HIGH SPEED CAN DAMAGE ROBOTIC DRIVETRAINS

Higher risk for hybrid high-speed cobots that switch between:

- Low speed mode with human-robot collaboration.
- High speed mode in absence of operators.

An error by the human operator in collaborative mode can lead to catastrophic failure of the robot's hardware in high-speed mode.

Software (active compliance) is not fast enough to mitigate a collision at high speed. **An overload clutch (passive compliance) is required additionally.**

- High rigidity is required in nominal operation to achieve high dynamics.
- Low rigidity is required upon collision.

The collaborative mode requires external load estimation based on joint torque sensing. The clutch requires decoupling detection.

WHAT? OVERLOAD CLUTCH WITH INTEGRATED TORQUE SENSING

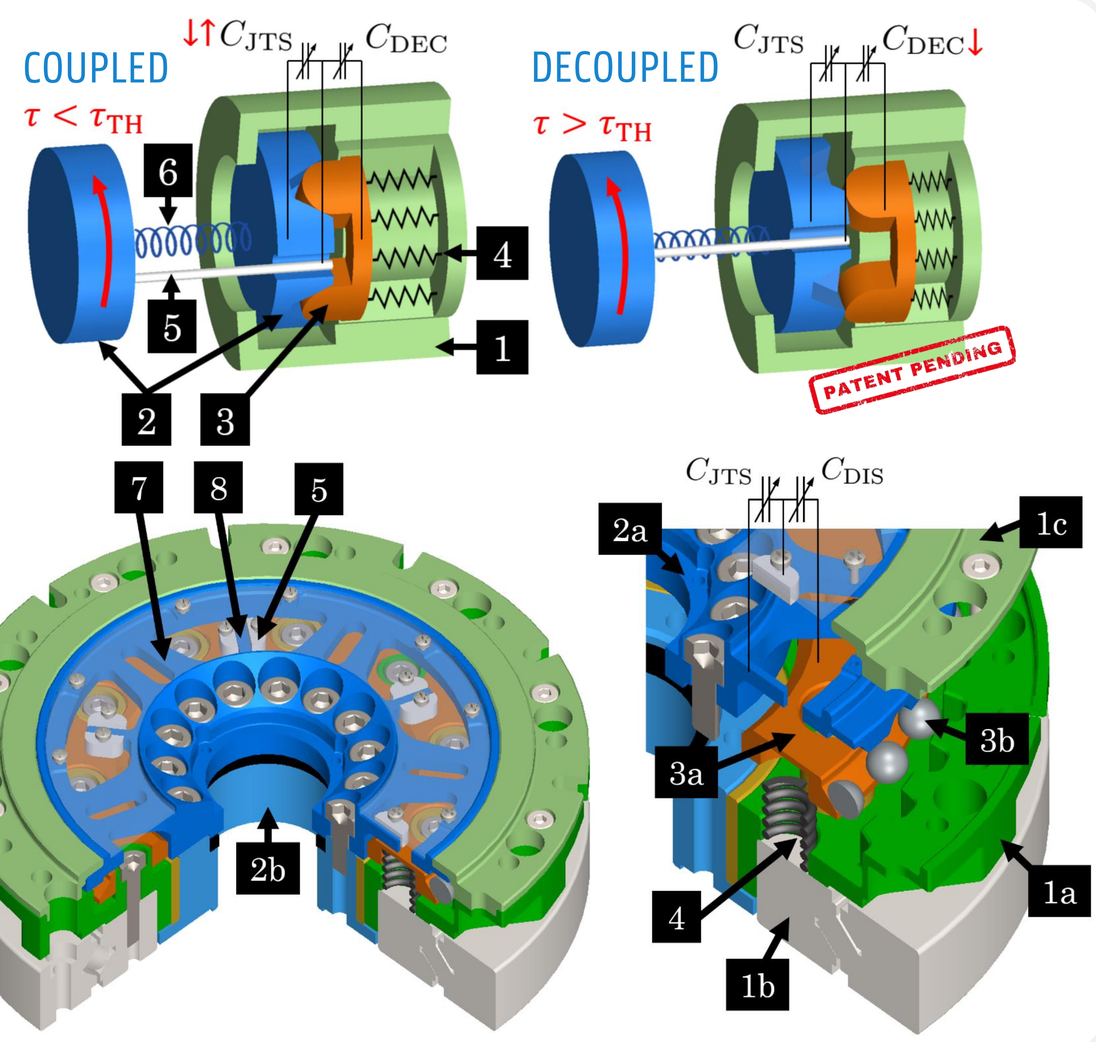
Combined friction and cam clutch . . .

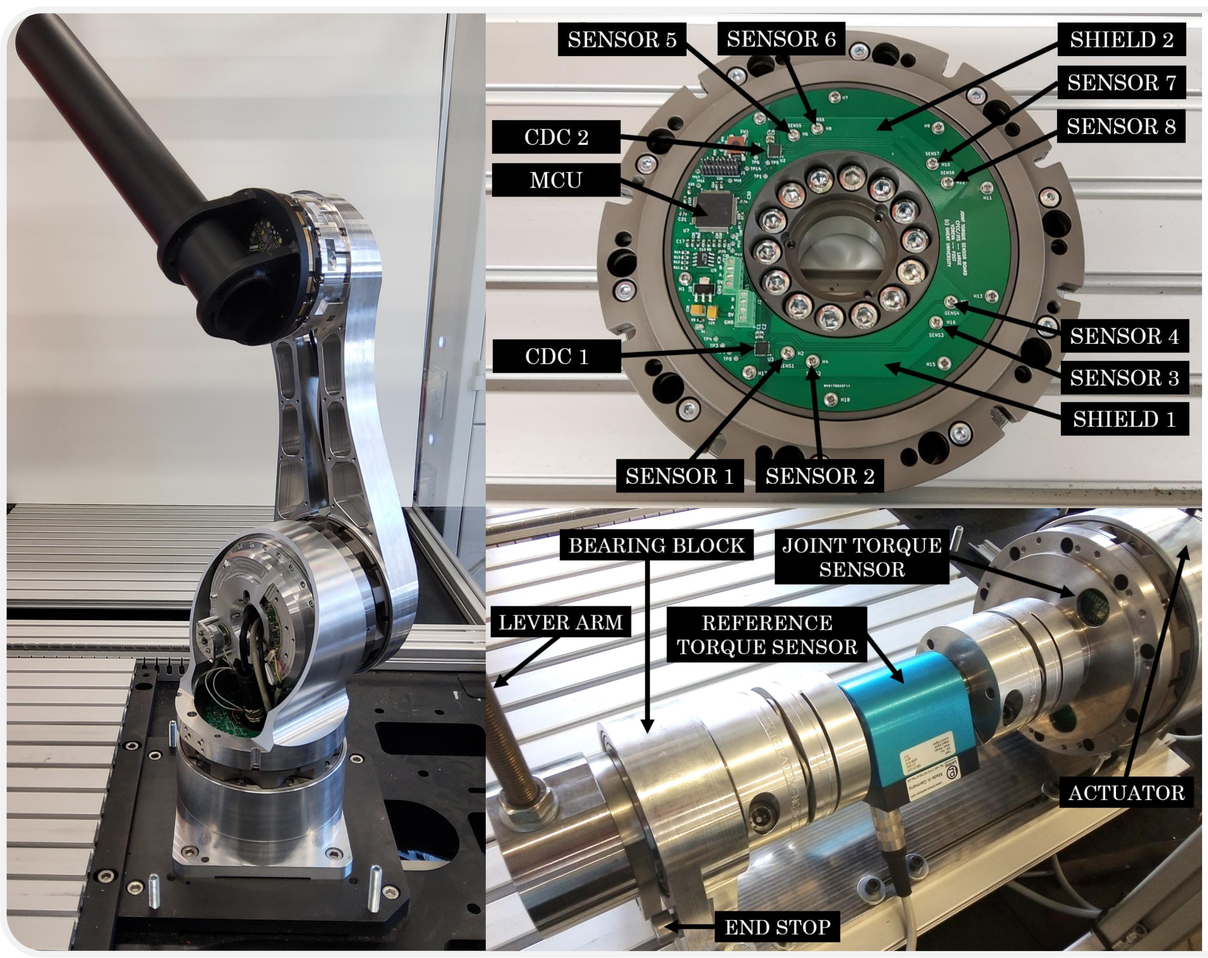
- Clutch output 1 is coupled with input flange 2 through form closure (cam) and force closure (friction). Spring plate 3 is pushed by springs 4 in the recess of 2 .
- If the collision force exceeds the clutch threshold, $\tau > \tau_{\mathrm{TH}}$, the clutch decouples. **Sufficient residual torque remains to counteract gravity.**
- Due to the cam, a **unique relative position of input and output flange exists avoiding recalibration** of the robot after recoupling the clutch.

. . . with integrated joint torque sensing and clutch decoupling detection.

- Input flange 2 is made compliant, represented by torsion spring 6 . An electrode 5 is mechanically fixed (but electrically isolated) to one halve. The change in capacitance $\downarrow\uparrow C_{\mathrm{JTS}}$ is related to the torque transmitted by the clutch when the torque is below the clutch threshold: $\tau < \tau_{\mathrm{TH}}$. A capacitance drop $C_{\mathrm{DEC}}\downarrow$ signals clutch decoupling.

The actual implementation resembles a spoked 7 wheel with multiple paired electrodes 5 facing several protrusions 8 .

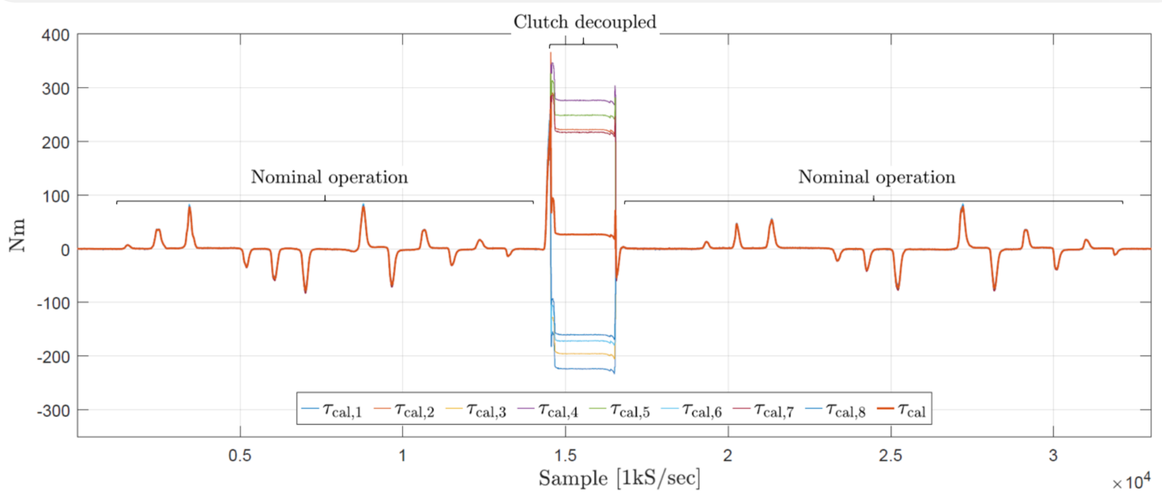




HOW? PROOF OF CONCEPT THROUGH SIMULATION AND EXPERIMENTS

High-speed collision experiments prove that the actuator can continue its high-speed operation after an auto-reset procedure.

After calibration through comparison with a reference torque sensor, the clutch is loaded below the threshold, decoupled, recoupled and loaded again. **Clutch decoupling can be clearly distinguished from joint torque.**



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