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Title

Electromechanical TVC using direct engine deflection measurement feedback for reusable stages

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Abstract

Most commonly, control architecture of electromechanical TVC (Thrust Vector Control) is made of nested loops using actuator stroke, electrical motor rotating speed and phase currents feedbacks, sometimes coupled with additional actuator force feedback to increase damping of selected dynamics whenever needed. With such an architecture, all the sensors are directly put on TVC equipment, which makes it handy to control all along product life cycle. The present paper focuses on the benefits of adding (or replacing actuator stroke by) a direct engine deflection measurement feedback in the frame of liquid propulsion. Main motivations are on the one hand a potential simplification of the gimbal joint design and the actuator design aiming at reducing their cost and on the other hand static accuracy improvement or simplified achievement which is of particular interest for reusable launchers: first stages indeed request the use of multi-engine bay to achieve high range thrust modularity, leading in the end to very compact engines stacking. More direct engine deflection assessment allows a better relative positioning of the engines, enabling to avoid mechanical or thermal interferences between engines especially in case of failure of one engine TVC. From a control standpoint, different architectural options are discussed to handle the fact with such a feedback there is no co-localization of the sensor and the effector which can affect the stability of the TVC control loop. Also the risk of conflict between engine deflection feedback and actuator force feedback is analyzed to be able to reject perturbations of various frequency ranges. Finally a control structure is proposed to handle the different control objectives (stability, set-point tracking and regulation). Going from functional to physical architecture, considerations about sensor technology and where to implement it are then presented, taking into account the engine environment constraints. The preferred solution here is to put one angular sensor per gimbal joint degree of freedom. From those measurements, useful data along actuation lines can be derived based on actuators accommodation (TVC electronics control unit both powering the sensor and implementing its related measurement and treatment chain). Finally, from a programmatic standpoint, in the near future, the first potential application for ArianeGroup might be to equip Prometheus Mark II engines with such a feature in the frame of Themis T3 demonstrator, to be able to increase its Integration Readiness Level for next generation of reusable launchers.