Learning-based Health Aware Model Predictive Control: Case Study of Gas-Lift Oil Wells and Haber-Bosch Process

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Abstract: Process safety has become an increasingly important concern across many industrial sectors. This can be seen in how maintenance strategies have evolved from reactive maintenance approaches toward preventive and predictive maintenance paradigms such as condition-based monitoring. These systems monitor the health of equipment and can provide estimates of its remaining useful life, thereby supporting better maintenance planning and decision-making (Escobet *et al*., 2012). The same health information can also be used at the control level. Instead of only using health indicators to decide when maintenance should be performed, they can be incorporated directly into the control strategy of process systems (Verheyleweghen, 2020). This has led to the development of health-aware controllers, whose objective is not only to achieve process performance, but also to operate the system in a way that respects its current health condition and expected degradation over a given operating horizon (Matias & Jäschke, 2025).

Among the proactive approaches, health-aware model predictive control (HAMPC) has emerged as an important framework. HAMPC combines the optimization-based decision-making capability of model predictive control with health and degradation information, allowing the controller to balance economic or performance objectives with the need to preserve equipment health and maintain safe operation (Verheyleweghen, 2020). Degradation processes are usually very slow thus long prediction horizons are inevitable, creating very large Non-linear Programs (NLPs) to be solved at every time step which is computationally taxing (Turan *et al*., 2025). Moreover, as the system grows larger in size and complexity, the greater the demand for computational resources. To alleviate this burden, various strategies have been devised such as compact parametrization of the MPC law by neural networks, imitation learning, and approximate dynamic programming (Karg & Lucia, 2020). Most recently, one-step learning-based MPCs have gained more ground which use surrogate models which learn the optimal cost-to-go values offline and are later deployed online leading to significantly lower computational burden hence faster online control with reasonable control performance (Turan *et al*., 2025).

A one-step health-aware Economic MPC has been employed for a gas-lift oil well with aim of maximizing oil production while keeping the erosion of the production choke at a minimum for a planned production epoch. An Input-Convex Neural Network (ICNN) was used to learn the optimal cost to go for various initial erosion values and prediction horizon. Good closed-loop performance of the one-step EMPC was observed for some initial values. A similar controller is being developed for an ammonia synthesis loop for maximizing ammonia yield while taking into consideration the heat exchanger fouling and compressor degradation.

Keywords: Process Safety, Health-Aware Control, Model Predictive Control, Surrogate Models, Cost-to-go

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