Evolutionary Industrial Design Optimisation using HARPPP

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Currently, industrial geometric design – such as shapes of impellers, pellets, beds, vessels, baffles or placement of any process assembly such as heat recovery or reactant injection points in larger plants – is virtually always done empirically, by human experts with vast domain experience. Improvements are done in very small steps based on well-known previous designs, and one design iteration may take years to go from CAD drawings to prototype manufacture and finally experimental campaigns; a single such design iteration may form the basis of an entire grant.

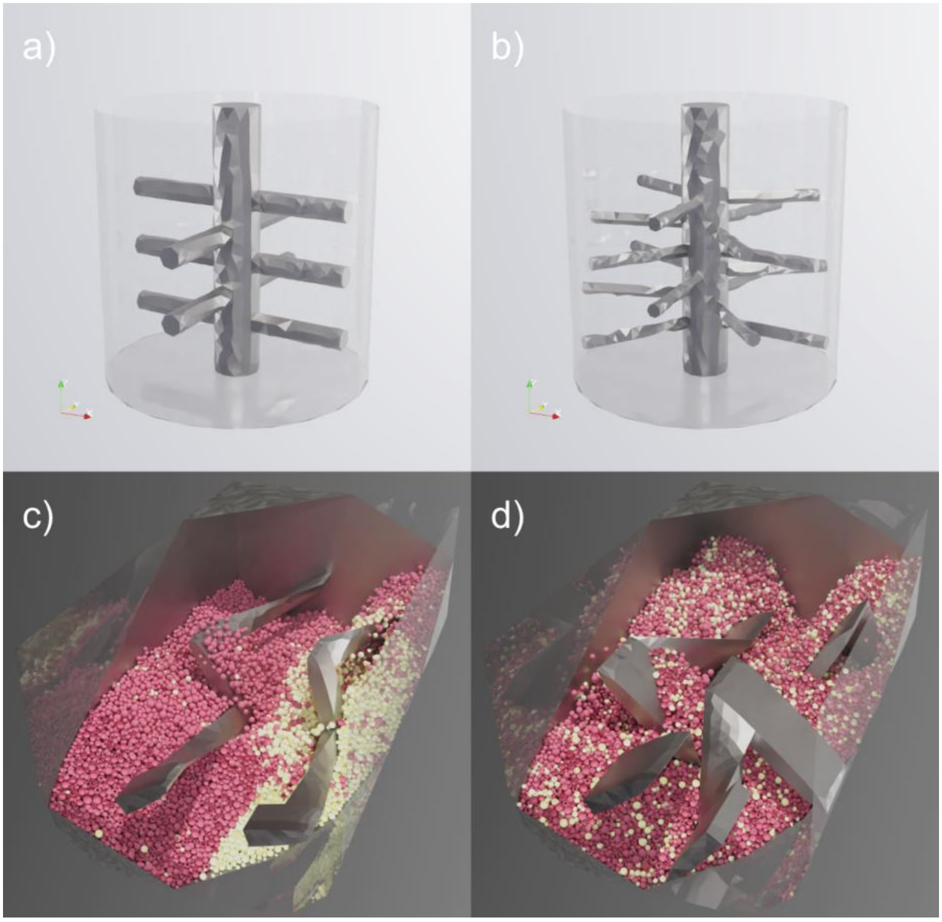

Figure 1. Two design optimisation case studies: panel a) shows an industry-standard attritor design used in milling, while panel b) depicts a HARPPP-evolved design achieving 24% reduction in power input for the same force impacted on grinding media. Panel c) shows an industry-standard Z-mixer used for mixing powders, after 20 s of mixing two particle species (red 75%, yellow 25%) at 30 RPM. Panel d) shows a HARPPP-evolved design achieving a 1360% improvement in mixing rate, as measured by the Lacey mixing index.

To solve this, we have developed HARPPP, a highly autonomous computational solution to optimise geometric designs in conjunction with physically-based simulations: given only a CAD model of the system and details of the material it processes, HARPPP uses AI to design and re-design the system of interest, iteratively improving its function toward a goal (e.g. “minimise power draw” or “maximise throughput”) defined by the user.

The optimisation backend was implemented in an open-source Python library, providing an interface that is easy to use, but powerful enough to automatically parallelise arbitrary user scripts through code inspection and metaprogramming. It was used successfully from laptop-scale shared-memory machines to multi-node supercomputing clusters on BlueBEAR.

References

[1] Martins JR, Ning A. Engineering design optimization. Cambridge University Press; 2021 Nov 18.