Penerapan Multi-objective Optimization dengan Adaptive Switching Metamodeling Framework dan Ensemble Surrogate Model untuk Tahap Awal Desain Kapal = Implementation of Multi-Objective Optimization with Adaptive Switching Metamodeling Framework and Ensemble Surrogate Model in Early Stages of Ship Design

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Abstrak

Pada tahap awal desain kapal, optimasi dimensi utama memiliki dampak yang signifikan dalam menentukan kinerja kapal dan total cost of ownership. Penelitian ini berfokus pada pendekatan multi-objective optimization (MOP) dengan surrogate model untuk tahap awal desain kapal. Penelitian ini menerapkan pendekatan ensemble dari 3 surrogate model: PR (Polynomial Regression), Kriging, dan BPNN-PSO (Backpropagation Neural Networks – Particle Swarm Optimizer) dan adaptive switching metamodeling (ASM) framework pada MOP. Framework ini didapatkan dari taksonomi surrogate model berdasarkan bagaimana fungsi objective dan constraint dimodelkan secara independen atau agregat. Hasil akurasi surrogate model menunjukkan ensemble surrogate model mempunyai performa terbaik dengan Mean Absolute Error (MAE) 10.75 dan R2 0.98. Kemudian, hasil optimization menunjukkan kombinasi Kriging dengan ASM memberikan performa terbaik dengan nilai Inverted Generational Distance (IGD) paling kecil dan hypervolume paling besar dibandingkan kombinasi lainnya. Di sisi lain, framework dengan fungsi objective dan constraint dioptimalkan secara independen (framework M1-2), mendapatkan performa IGD yang paling baik untuk ensemble maupun individual surrogate model. Varian solusi desain dari kombinasi Kriging dan ASM framework memberikan nilai objective kebutuhan daya 60% lebih kecil dan berat baja 7% lebih kecil (dengan waktu desain 300 kali lebih cepat), jika dibandingkan dengan hasil desain oleh desainer kapal.

.....In the early stages of ship design, optimization of main ship dimensions significantly impacts ship performance and the total cost of ownership. This research focuses on the Multi-Objective Optimization (MOP) approach with the surrogate model for the early stages of ship design. This study applies an ensemble approach of 3 surrogate models: PR (Polynomial Regression), Kriging, and BPNN-PSO (Backpropagation Neural Networks - Particle Swarm Optimizer) and Adaptive Switching Metamodeling (ASM) framework on MOP. This framework is obtained from the surrogate model taxonomy based on how the objective and constraint functions are modeled independently or in aggregate. The results of the surrogate model accuracy show that the ensemble surrogate model has the best performance with a Mean Absolute Error (MAE) of 10.75 and R2 of 0.98. Then the optimization results show that the combination of Kriging with the ASM framework has the best performance with the smallest IGD value and the largest hypervolume compared to other combinations. Meanwhile, frameworks with objective and constraint functions optimized independently (framework M1-2) have the best IGD performance for both ensemble and individual surrogate models. The design solution variant of the Kriging and ASM framework has objective values of 60% less effective power and 7% less steel weight requirements (with design time 300 times faster), when compared to the original design by the expert/ship designer.