– Supplementary Online Material –
Data-Driven Estimation of Hydrostatic Parameters in Early-Stage Ship Design

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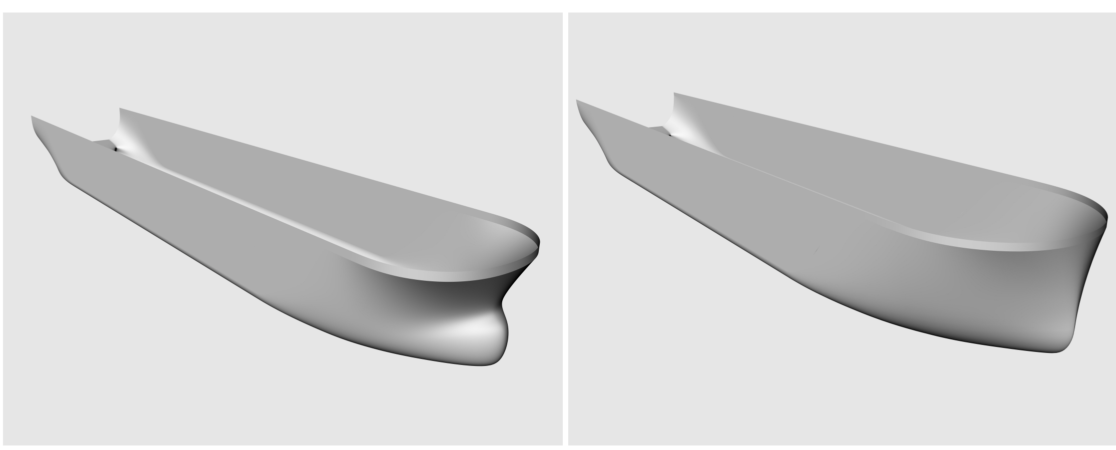
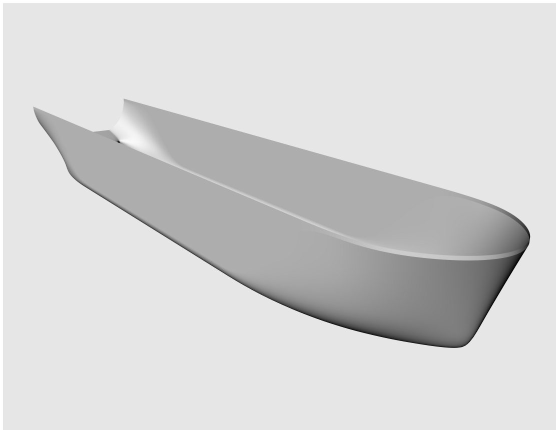
IMAGES OF REPRESENTATIVE HULLS FROM EACH CLUSTER OF SYNTHETIC HULLS

To provide a clear understanding of the diversity in the generated dataset, representative hulls from each cluster of synthetic hulls are illustrated in Figure 1. These examples highlight the distinct geometric variations captured through the clustering process, showcasing differences in proportions, curvature, and overall hull form. The selected hulls serve as visual references for interpreting the subsequent analysis and demonstrate the effectiveness of the synthetic generation procedure in producing a broad and varied design space.

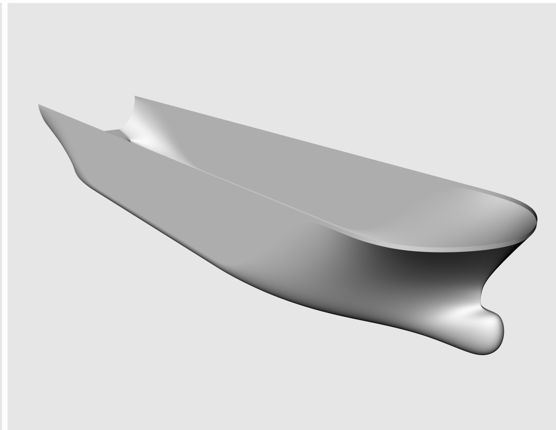


(a) Synthetic Hull 1 (SH1) (b) Synthetic Hull 2 (SH2)

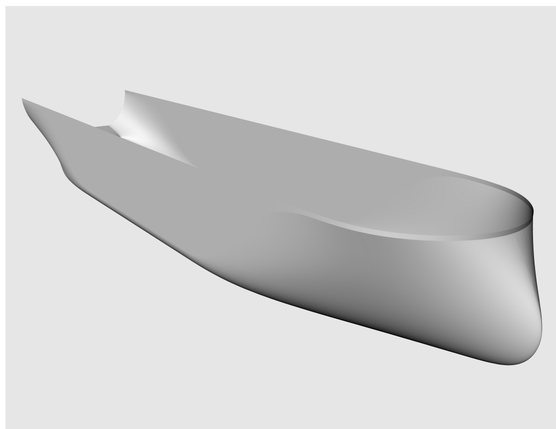
FIGURE 1: 3D geometry of representative hulls from each cluster of synthetic hulls



(c) Synthetic Hull 3 (SH3)



(d) Synthetic Hull 4 (SH4)



(e) Synthetic Hull 5 (SH5)

FIGURE 1: 3D geometry of representative hulls from each cluster of synthetic hulls

DATASET

The dataset consists of 17 real hulls and 80 synthetically generated hulls, as summarised in Table 1. Real hulls are denoted using their original identifiers (e.g., AMSBL-01-03, AMSBL-06-07, etc.), while synthetic hulls follow a systematic naming scheme. Each cluster representative is labelled as Synthetic Hull (SH) followed by a number (e.g., SH1, SH2, ...), and the corresponding transformed variants derived from that representative are indexed sequentially (e.g., SH1_01, SH1_02, $\cdots$). This convention ensures consistency across the dataset and provides a clear distinction between the representative hulls and their parametric variants.

In this dataset, the input features are four principal hull form parameters: waterline length (L_{WL}), beam (B), draft (T), and block coefficient (C_B). These represent the fundamental design variables that define the geometry of a hull. The remaining parameters are treated as output features, which are computed hydrostatic properties derived from the input hull form. These include the waterplane area (WSA), prismatic coefficient (C_P), waterplane coefficient (C_{WP}), longitudinal center of buoyancy (LCB), longitudinal center of flotation (LCF), vertical center of buoyancy (KB), transverse metacentric height (KM_T), longitudinal metacentric height (KM_L), and tonnes per centimetre immersion (TPC). This separation ensures a clear distinction between the basic defining variables of a hull and the resultant performance-related characteristics.

TABLE 1: Dataset comprised of 17 real hulls and 80 synthetic hulls

Hull ID	Input Features				Output Features								
	L_{WL}	B	T	C_B	WSA	C_P	C_{WP}	LCB	LCF	KB	KM_T	KM_L	TPC
AMSBL-01-03	64.033	10.800	3.857	0.85	1086.353	0.86	0.92	0.854	-0.559	1.993	4.525	84.602	6.363
AMSBL-06-07	67.427	12.500	4.000	0.87	1264.999	0.87	0.94	1.506	-0.478	2.066	5.387	94.339	7.922
AMSBL-08-10	55.745	12.000	1.900	0.81	776.623	0.81	0.89	-0.095	-1.631	0.984	7.573	127.323	5.920
BSEL-05-07	74.764	16.000	4.200	0.85	1651.075	0.85	0.93	1.952	-0.743	2.181	7.369	110.136	11.145
BSEL-29-43	81.521	18.000	4.500	0.84	1956.836	0.85	0.93	0.721	-1.782	2.367	8.560	123.130	13.660
DSL-H-18	75.715	13.000	3.300	0.81	1313.072	0.82	0.92	0.438	-1.414	1.726	6.173	143.470	9.043
DSL-H-19-21	80.321	16.000	4.100	0.86	1764.488	0.87	0.93	1.635	-0.841	2.120	7.406	128.380	11.995
DTC-01-08	70.094	11.020	3.600	0.90	1177.021	0.91	0.95	0.486	-0.719	1.857	4.663	111.790	7.351
DTC-OT-01-02	71.362	11.500	3.630	0.88	1204.630	0.88	0.95	1.991	0.291	1.866	4.922	116.122	7.753
MSDL-37	95.4	17.000	4.600	0.84	2232.551	0.84	0.92	2.148	-0.996	2.394	7.672	162.729	14.981
MSDL-38-39	85.55	18.250	4.500	0.84	2075.045	0.84	0.93	0.954	-2.007	2.361	8.729	133.318	14.449
MSDL-43	81.384	15.501	4.270	0.83	1738.507	0.84	0.94	0.744	-1.336	2.259	7.295	134.381	11.881
MSDL-47-52	83.2	16.000	4.270	0.84	1807.578	0.84	0.92	0.851	-2.016	2.234	7.385	131.737	12.280
MSDL-76-77	96.207	18.000	4.500	0.87	2340.974	0.88	0.95	1.946	-0.616	2.335	8.485	170.797	16.370
MSDL-80	74.247	14.250	4.500	0.86	1562.418	0.87	0.95	2.034	-0.404	2.349	6.246	104.663	10.030
RSL-57-58	81.12	14.000	4.350	0.86	1669.569	0.86	0.94	1.986	-0.656	2.255	6.088	125.092	10.625
TAM-53	79.565	15.200	4.340	0.84	1693.228	0.85	0.94	0.676	-1.329	2.254	6.870	122.340	11.320
SH1	83.728	15.200	4.500	0.90	1896.977	0.90	0.97	0.954	-1.011	2.337	6.786	133.675	12.285
SH1_01	57.336	10.094	3.801	0.9	962.433	0.91	0.97	0.65	-0.649	1.971	4.293	74.926	5.598
SH1_02	59.184	11.061	3.627	0.9	1026.385	0.91	0.97	0.671	-0.67	1.881	4.803	83.342	6.332
SH1_03	67.523	11.393	3.364	0.9	1152.958	0.91	0.97	0.765	-0.764	1.745	5.087	116.067	7.442
SH1_04	67.886	10.06	3.856	0.9	1139.755	0.91	0.97	0.769	-0.768	2	4.273	102.81	6.606
SH1_05	66.415	12.261	4.327	0.89	1309.634	0.9	0.96	0.745	-0.876	2.25	5.263	88.038	7.838
SH1_06	68.308	10.733	3.52	0.89	1138.098	0.9	0.96	0.766	-0.901	1.83	4.669	113.383	7.056
SH1_07	68.543	13.554	4.011	0.87	1375.552	0.88	0.95	0.768	-1.164	2.097	6.079	100.263	8.849
SH1_08	88.766	15.937	4.312	0.89	2042.528	0.9	0.96	0.995	-1.169	2.243	7.352	156.064	13.617
SH1_09	93.514	16.382	4.496	0.89	2222.331	0.9	0.96	1.048	-1.232	2.338	7.516	166.067	14.746
SH1_10	94.805	15.261	4.467	0.89	2146.885	0.9	0.96	1.062	-1.249	2.323	6.845	171.695	13.927
SH1_11	62.18	11.277	4.083	0.88	1133.832	0.89	0.96	0.693	-0.936	2.129	4.834	81.681	6.715
SH1_12	63.227	11.429	3.388	0.88	1074.253	0.89	0.96	0.705	-0.952	1.767	5.115	100.891	6.92
SH1_13	63.412	10.57	4.387	0.86	1141.189	0.87	0.95	0.712	-1.2	2.3	4.517	78.962	6.35
SH1_14	94.493	14.617	4.137	0.88	2011.016	0.89	0.96	1.052	-1.42	2.158	6.643	183.521	13.228
SH1_14	73.809	12.439	3.946	0.85	1360.834	0.86	0.95	0.3	-1.46	2.076	5.529	118.255	8.685
SH1_15	55.422	10.877	3.593	0.87	933.531	0.88	0.95	0.617	-0.939	1.879	4.742	73.56	5.743
SH2	80.000	15.000	4.500	0.87	1754.556	0.88	0.95	0.329	-1.342	2.353	6.729	122.008	11.452
SH2_01	60.139	11.385	3.85	0.87	1058.577	0.88	0.95	0.245	-1.006	2.013	4.959	81.035	6.535

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TABLE 1: Dataset comprised of 17 real hulls and 80 synthetic hulls (Continued)

Hull ID	Input Features				Output Features								
	L_{WL}	B	T	C_B	WSA	C_P	C_{WP}	LCB	LCF	KB	KM_T	KM_L	TPC
SH2_02	69.952	13.896	4.187	0.89	1453.548	0.9	0.96	0.292	-0.955	2.177	6.188	100.517	9.359
SH2_03	75.111	10.84	3.092	0.87	1168.348	0.88	0.95	0.306	-1.257	1.617	4.943	155.1	7.771
SH2_04	79.143	14.576	4.136	0.87	1659.939	0.88	0.95	0.323	-1.324	2.163	6.658	129.553	11.01
SH2_05	64.513	10.104	4.11	0.88	1097.172	0.89	0.96	0.267	-0.98	2.143	4.31	87.335	6.249
SH2_06	68.547	10.078	4.442	0.86	1193.269	0.87	0.95	0.277	-1.252	2.33	4.337	91.315	6.564
SH2_07	70.969	10.885	3.296	0.86	1128.643	0.87	0.95	0.287	-1.296	1.729	4.884	130.278	7.34
SH2_08	76.599	13.631	3.935	0.86	1501.662	0.87	0.95	0.31	-1.399	2.064	6.209	127.499	9.921
SH2_09	80.281	12.492	4.102	0.86	1514.784	0.87	0.95	0.324	-1.466	2.151	5.491	134.326	9.529
SH2_10	81.747	13.911	4.234	0.86	1668.179	0.87	0.95	0.33	-1.493	2.221	6.233	134.994	10.805
SH2_11	86.277	13.336	4.083	0.86	1688.67	0.87	0.95	0.349	-1.576	2.141	5.965	155.508	10.933
SH2_12	87.762	16.268	4.432	0.86	2010.728	0.87	0.95	0.355	-1.603	2.325	7.566	148.52	13.566
SH2_13	63.418	12.403	3.344	0.85	1097.865	0.86	0.95	0.258	-1.255	1.759	5.811	102.97	7.441
SH2_15	93.444	14.408	4.575	0.83	1968.962	0.84	0.94	0.377	-2.134	2.422	6.444	163.189	12.62
SH3	63.768	12.000	3.500	0.84	1070.692	0.84	0.94	0.852	-0.779	1.834	5.452	100.041	7.199
SH3_01	55.016	10.5	3.32	0.84	849.399	0.85	0.94	0.732	-0.648	1.738	4.656	78.777	5.446
SH3_02	64.248	12.734	3.938	0.84	1193.452	0.85	0.94	0.855	-0.756	2.062	5.68	90.642	7.713
SH3_03	65.706	12.992	4.511	0.83	1298.958	0.84	0.94	0.876	-0.849	2.367	5.662	83.224	8.008
SH3_04	71.482	10.623	4.399	0.83	1243.794	0.84	0.94	0.953	-0.924	2.309	4.567	100.442	7.123
SH3_05	74.921	13.004	3.742	0.83	1366.673	0.84	0.94	0.999	-0.969	1.964	5.942	128.685	9.139
SH3_06	96.693	16.174	4.521	0.85	2197.776	0.86	0.95	1.28	-1.028	2.362	7.435	177.17	14.815
SH3_07	69.681	12.907	3.742	0.82	1258.649	0.83	0.93	0.928	-0.985	1.968	5.895	111.548	8.394
SH3_08	70.355	12.075	4.528	0.82	1323.607	0.83	0.93	0.937	-0.994	2.382	5.222	94.705	7.929
SH3_09	77.655	13.05	3.862	0.82	1426.404	0.83	0.93	1.034	-1.098	2.031	5.921	133.897	9.458
SH3_10	77.892	13.059	4.506	0.82	1525.737	0.83	0.93	1.038	-1.1	2.37	5.709	116.088	9.494
SH3_11	89.142	14.895	4.343	0.82	1857.867	0.83	0.93	1.187	-1.26	2.284	6.791	156.802	12.393
SH3_12	90.304	13.468	4.41	0.82	1779.263	0.83	0.93	1.203	-1.276	2.32	5.948	158.491	11.352
SH3_13	58.235	10.095	4.148	0.81	950.524	0.82	0.93	0.772	-0.894	2.186	4.358	71.206	5.459
SH3_14	65.379	11.678	3.677	0.81	1095.89	0.82	0.93	0.867	-1.004	1.938	5.216	100.073	7.09
SH3_15	67.512	11.493	3.243	0.81	1065.339	0.82	0.93	0.896	-1.037	1.709	5.309	120.356	7.205
SH4	58.275	12.000	3.500	0.81	976.258	0.82	0.92	0.560	-1.129	1.841	5.461	82.212	6.454
SH4_01	68.014	10.464	3.088	0.81	1004.183	0.82	0.92	0.651	-1.316	1.625	4.745	125.703	6.569
SH4_02	83.177	12.847	3.813	0.8	1503.535	0.81	0.92	0.789	-1.737	2.01	5.824	151.963	9.806
SH4_03	93.779	13.921	4.157	0.8	1840.265	0.81	0.92	0.889	-1.959	2.191	6.299	177.03	11.98
SH4_04	58.861	11.154	4.235	0.79	1028.308	0.8	0.91	0.556	-1.323	2.237	4.829	69.7	5.989
SH4_05	61.35	11.665	3.99	0.79	1068.16	0.8	0.91	0.58	-1.379	2.107	5.116	79.897	6.528
SH4_06	61.592	12.19	3.429	0.79	1033.596	0.8	0.91	0.582	-1.384	1.811	5.634	93.043	6.848

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TABLE 1: Dataset comprised of 17 real hulls and 80 synthetic hulls (Continued)

Hull ID	**Input Features**				**Output Features**								
	L_{WL}	B	T	C_B	WSA	C_P	C_{WP}	LCB	LCF	KB	KM_T	KM_L	TPC
SH4_07	64.858	10.533	2.934	0.79	933.496	0.8	0.91	0.612	-1.458	1.55	4.886	119.779	6.231
SH4_08	65.024	11.771	4.359	0.79	1183.36	0.8	0.91	0.614	-1.462	2.302	5.107	82.289	6.982
SH4_09	76.391	13.945	4.184	0.79	1502.134	0.8	0.91	0.72	-1.717	2.21	6.31	117.222	9.717
SH4_10	87.558	14.865	4.218	0.79	1792.504	0.8	0.91	0.797	-1.984	2.229	6.855	152.32	11.878
SH4_11	66.398	13.2	4.304	0.78	1275.702	0.79	0.91	0.603	-1.61	2.279	5.858	86.691	7.95
SH4_12	71.541	12.897	3.667	0.78	1266.545	0.79	0.91	0.649	-1.735	1.942	5.952	116.959	8.369
SH4_13	79.78	12.975	4.33	0.78	1515.711	0.79	0.91	0.723	-1.935	2.293	5.73	123.425	9.39
SH4_14	82.34	14.617	4.381	0.78	1686.812	0.79	0.91	0.746	-1.997	2.32	6.631	129.847	10.917
SH4_15	89.662	12.897	3.987	0.77	1628.097	0.78	0.9	0.815	-2.32	2.115	5.809	167.937	10.425
SH5	59.860	12.000	3.500	0.77	967.727	0.78	0.90	0.047	-1.594	1.862	5.496	86.026	6.484
SH5_01	58.481	10.633	2.966	0.77	828.037	0.78	0.9	0.046	-1.582	1.579	4.948	96.341	5.603
SH5_02	69.565	10.488	3.651	0.77	1062.036	0.78	0.9	0.055	-1.882	1.944	4.607	110.875	6.574
SH5_03	91.075	14.548	4.403	0.78	1829.744	0.79	0.91	0.072	-2.337	2.339	6.58	157.308	12.007
SH5_04	61.345	12.045	3.371	0.76	980.3	0.77	0.9	0.048	-1.746	1.799	5.61	93.464	6.618
SH5_05	63.75	10.676	3.954	0.76	1014.811	0.77	0.9	0.05	-1.814	2.11	4.662	86.509	6.096
SH5_06	67.604	12.476	3.594	0.76	1130.349	0.77	0.9	0.053	-1.924	1.918	5.753	106.335	7.555
SH5_07	68.144	12.109	4.189	0.76	1193.815	0.77	0.9	0.053	-1.939	2.235	5.335	93.258	7.391
SH5_08	69.607	13.586	3.665	0.76	1236.98	0.77	0.9	0.054	-1.981	1.956	6.415	110.507	8.471
SH5_09	70.347	11.521	3.898	0.76	1159.26	0.77	0.9	0.055	-2.002	2.08	5.095	106.324	7.259
SH5_10	72.264	11.709	3.219	0.76	1111.32	0.77	0.9	0.056	-2.057	1.718	5.489	134.925	7.579
SH5_11	73.734	11.38	4.145	0.76	1239.666	0.77	0.9	0.057	-2.099	2.212	4.979	109.912	7.516
SH5_12	55.494	10.121	3.747	0.75	833.569	0.76	0.89	0.042	-1.658	2.004	4.429	69.439	5.001
SH5_13	65.918	11.277	3.445	0.75	1012.261	0.76	0.89	0.05	-1.969	1.843	5.117	105.332	6.619
SH5_14	76.087	14.142	4.484	0.75	1490.481	0.76	0.89	0.058	-2.273	2.398	6.355	108.334	9.581
SH5_15	90.7	14.622	4.062	0.75	1737.505	0.76	0.89	0.069	-2.709	2.173	6.842	168.345	11.809

COMPARISON OF MODELS

To evaluate the predictive performance of the developed machine learning models, a comparative analysis was carried out using both the test and validation datasets. Figures 2–6 present the results across three commonly used error metrics: root mean square error (RMSE), mean absolute error (MAE), and coefficient of determination (R^2). For RMSE and MAE, lower values indicate better predictive accuracy, while for R^2, higher values reflect stronger agreement between predicted and actual values. The test set results (Figures 2–3) provide an unbiased measure of model generalisation, whereas the validation set results (Figures 4–6) further confirm the consistency and robustness of the models.

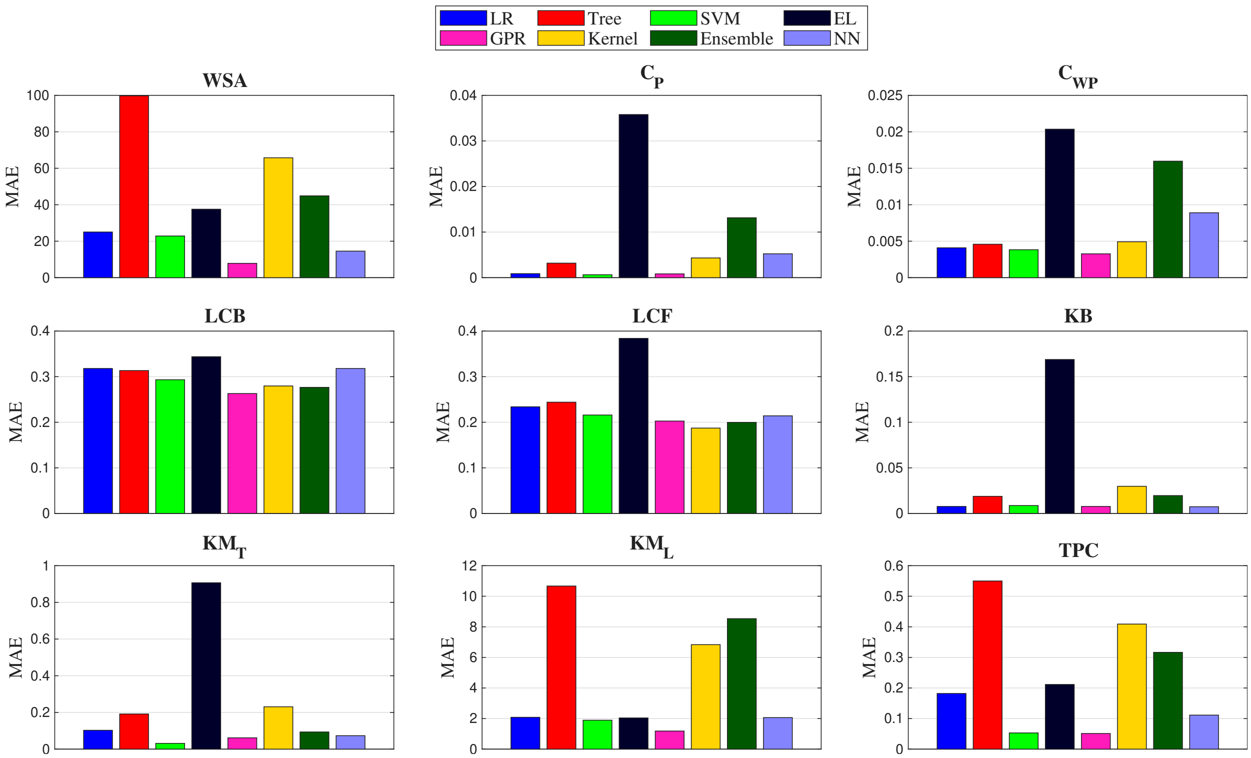

FIGURE 2: Comparison of ML models for predicting ship hydrostatic parameters on the *test* dataset using MAE.

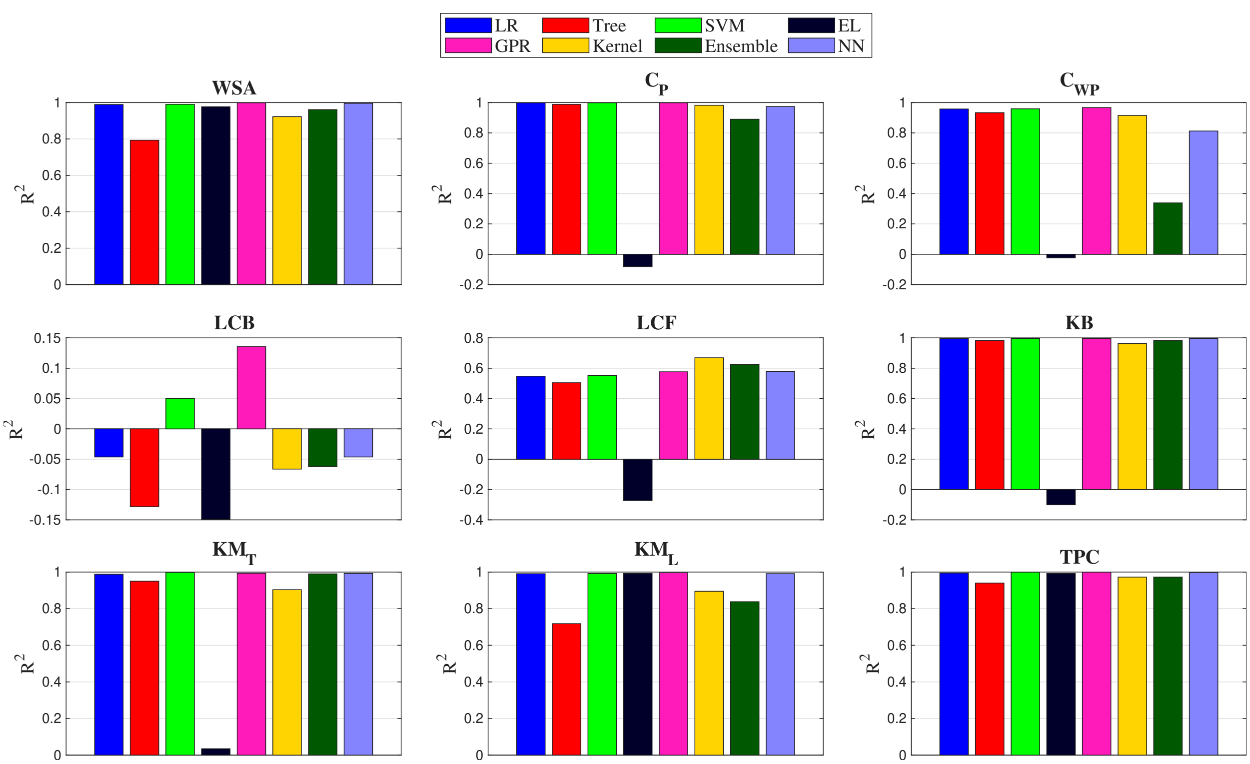

FIGURE 3: Comparison of ML models for predicting ship hydrostatic parameters on the *test* dataset using R^2.

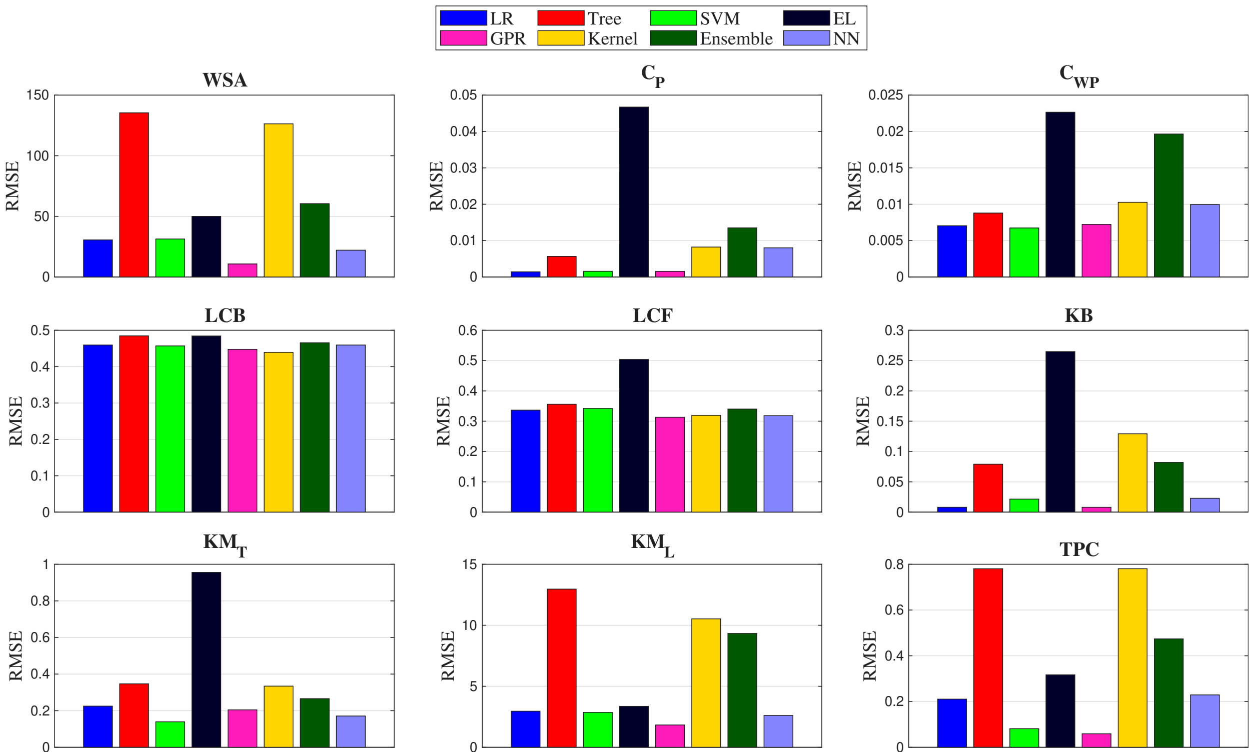

FIGURE 4: Comparison of ML models for predicting ship hydrostatic parameters on the *validation* dataset using RMSE.

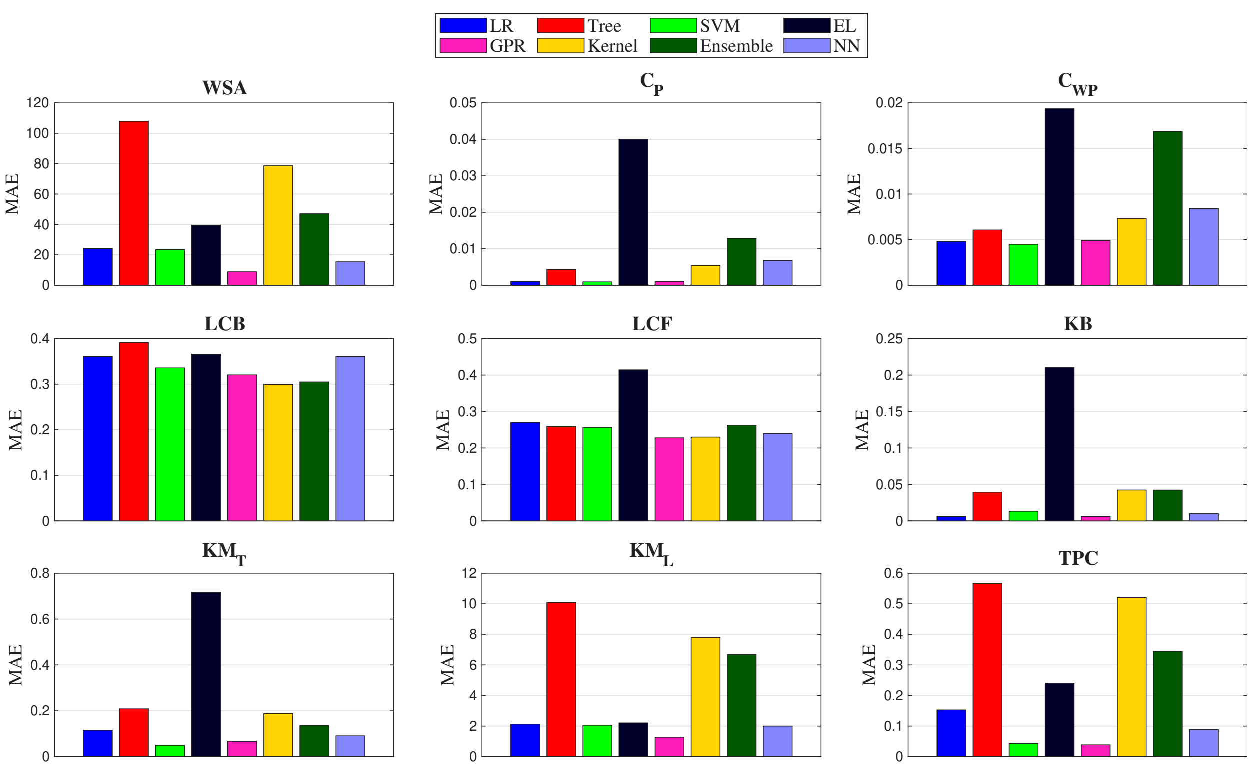

FIGURE 5: Comparison of ML models for predicting ship hydrostatic parameters on the *validation* dataset using MAE.

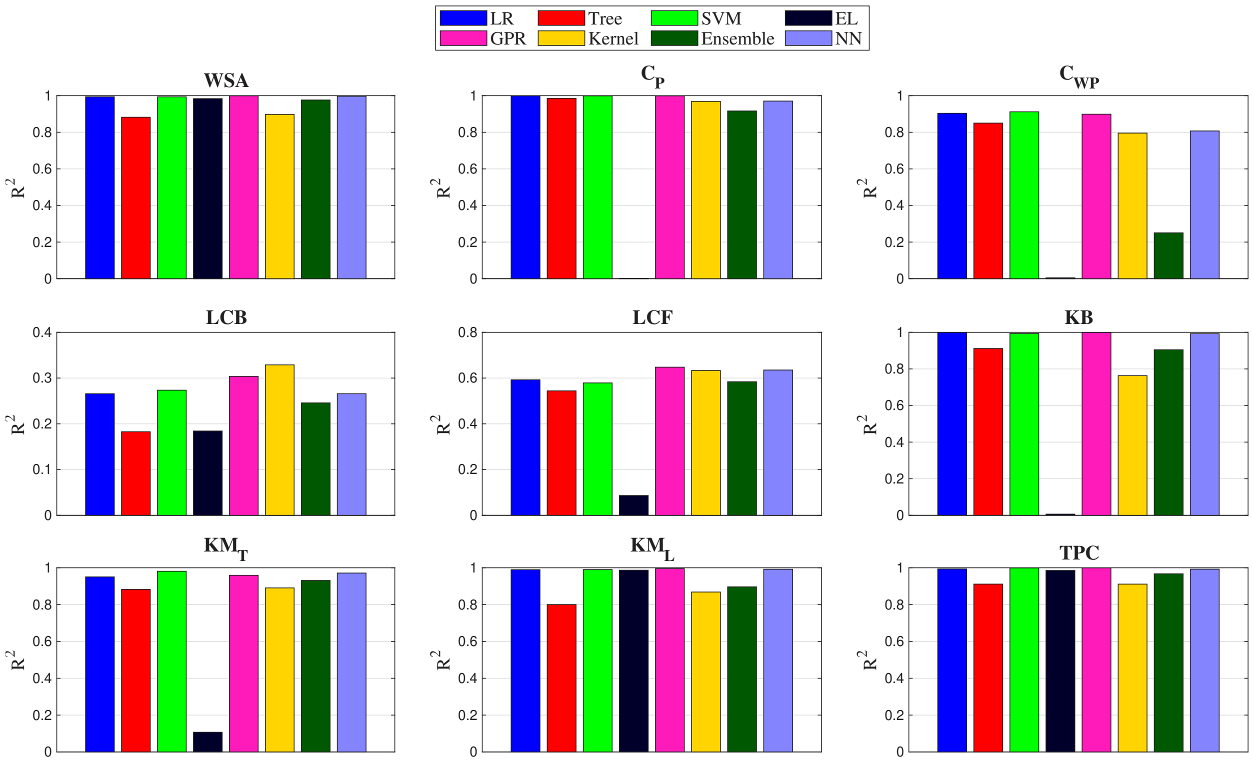

FIGURE 6: Comparison of ML models for predicting ship hydrostatic parameters on the *validation* dataset using R^2.