

JBC

**Cases 1.5 and 1.6
Self-Propulsion
and
ESD Performance**

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Overview

- Case 1.5a
 - Self-propulsion at ship-point
 - With propeller, without rudder
 - Without ESD
 - $FR_{z\theta}$: Free in heave and pitch
 - $Fn=0.142$, $Rn=7.46 \times 10^6$
 - 26 submissions
- Case 1.6a
 - With ESD
 - 26 submissions

13 Submissions with Actual Propeller Model for 1.5a

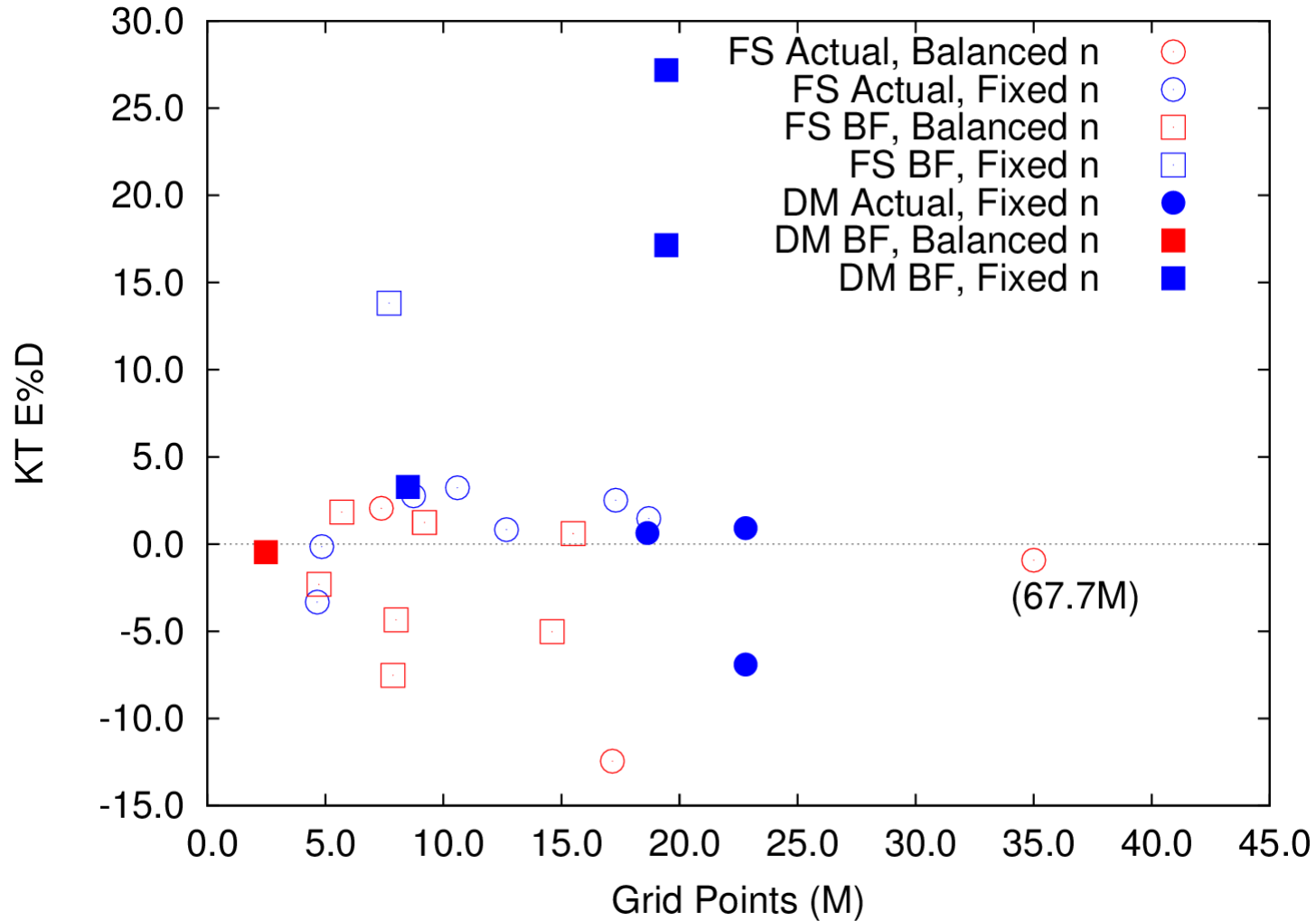
Organization (Code)	Free Surface	Prop. M.		CT	CF	CPV	KT	KQ	n(rps)	RT-T(N)
				x1000	x1000	x1000				
EFD(NMRI)	-	-	D	4.811	-	-	0.217	0.0279	7.8	18.2
ABS (OpenFOAM)	V	A	S	4.768	3.205	1.564	0.213	0.0284	7.842	-
			E%D	0.895	-	-	2.057	-1.682	-0.538	-
CNR/INSEAN (XNAVIS)	LS	A	S				0.210	0.0304		
			E%D				3.230	-8.960		
CSSRC (FLUENT)	V	A	S	4.757	3.139	1.619	0.223	0.0291	-	17.272
			E%D	-1.094	-	-	2.765	4.194	-	5.100
ECN/CNRS (ISISCFD/WF-EASM-RANSE)	V	A	S	4.661	3.149	1.512	0.214	0.0290	-	17.470
			E%D	3.110	-	-	1.470	-5.550	-	4.010
HHI (HiFoam)	V	A	S	4.841	3.128	1.713	0.217	0.0279	-	18.600
			E%D	-0.630	-	-	-0.140	0.100	-	-2.400
HHI (STRA-CCM+)	V	A	S	4.855	-	-	0.224	0.0294	-	18.100
			E%D	-0.910	-	-	-3.320	-5.380	-	0.770
IIHR (REX-DDES)	LS	A	S	4.812	3.210	1.600	0.219	0.0291	7.818	-
			E%D	-0.021	-	-	-0.922	-4.301	-0.231	-
MARIN (ReFreSCo)	V	A	S	4.663	3.065	1.598	0.212	0.0282	-	17.744
			E%D	3.085	-	-	2.517	-1.143	-	2.504
PNU (FLUENTv15)	V	A	S	5.177	3.166	2.011	0.244	0.0285	7.871	18.515
			E%D	-7.608	-	-	-12.442	-2.151	-0.910	-1.732
SHIME (OpenFOAM)	No	A	S	4.852	3.070	1.782	0.216	0.028	-	18.800
			E%D	-0.855	-	-	0.631	-1.853	-	-3.355
UDE (STAR-CCM+)	V	A	S	4.808	2.946	1.862	0.215	0.0264	-	18.600
			E%D	0.062	-	-	0.829	5.376	-	-2.198
UNI-ROSTOCK (OpenFOAM-SST)	No	A	S	5.210	3.554	1.656	0.215	0.027	-	21.450
			E%D	-8.293	-	-	0.921	4.659	-	-17.850
UNI-ROSTOCK (OpenFOAM-HYBRID)	No	A	S	5.075	2.830	2.245	0.232	0.029	-	19.518
			E%D	-5.487	-	-	-6.912	-2.150	-	-7.241

13 Submissions with Body Force Propeller Model for 1.5a

Organization (Code)	Free Surface	Prop. M.		CT	CF	CPV	KT	KQ	n(rps)	RT-T(N)
				x1000	x1000	x1000				
EFD(NMRI)	-	-	D	4.811	-	-	0.217	0.0279	7.8	18.2
CHALMERS-FLOWTECH (SHIPFLOW)	Pot.Flow	BL	S	4.754	3.097	1.657	0.226	0.0279	7.572	-
			E%D	1.180	-	-	-4.340	-0.080	2.930	-
CNR/INSEAN (XNAVIS-HO)	LS	BX	S				0.187	0.0268		
			E%D				13.825	3.943		
ECN/CNRS (ISISCFD/LRN-EASM-AD)	V	BX	S	4.625	3.108	1.517	0.214	0.0291	7.600	-
			E%D	3.870	-	-	1.240	-4.410	2.560	-
ECN/CNRS (ISISCFD/WF-EASM-AD)	V	BX	S	4.620	3.125	1.495	0.213	0.0291	7.620	-
			E%D	3.970	-	-	1.840	-4.190	2.310	-
HSVA (FreSCo+)	V	BV	S	4.652	-	-	0.206	0.0255	7.803	-
			E%D	-3.310	3.126	1.526	-5.020	-8.650	0.040	-
KRISO (WAVIS)	LS	BS	S	4.813	3.207	1.606	0.216	0.0280	7.863	-
			E%D	-0.042	-	-	0.599	0.000	-0.812	-
MARIC (FINEMarine)	V	BX	S	4.986	-	-	0.228	0.0278	7.800	18.200
			E%D	3.637	-	-	5.069	-0.358	-	
MIJAC (OpenFOAM)	No	BX	S	4.555	2.957	1.598	0.210	0.0270	-	16.784
			E%D	5.319	-	-	3.273	3.292	-	7.783
NMRI (NAGISA)	LS	BX	S	4.922	3.211	1.711	0.233	0.0293	7.560	-
			E%D	-2.310	-	-	-7.520	-5.090	3.130	-
SJTU (naoeFOAM)	V	BX	S	4.621	2.839	1.782	0.222	0.0285	7.691	-
			E%D	3.949	-	-	-2.304	-2.151	1.397	-
SOTON (OpenFOAM)	No	BP	S	5.190	3.636	1.554	0.180	0.0248	-	11.339
			E%D	-7.872		-	17.143	11.111	-	37.696
SOTON (STAR-CCM+)	No	BP	S	4.762	3.391	1.371	0.158	0.0226	-	11.601
			E%D	1.021	-	-	27.189	18.996	-	36.256
YNU (SURFv7)	No	BX	S	4.573	3.084	1.490	0.218	0.0281	7.450	-
			E%D	4.950	-	-	-0.460	-0.720	4.490	-

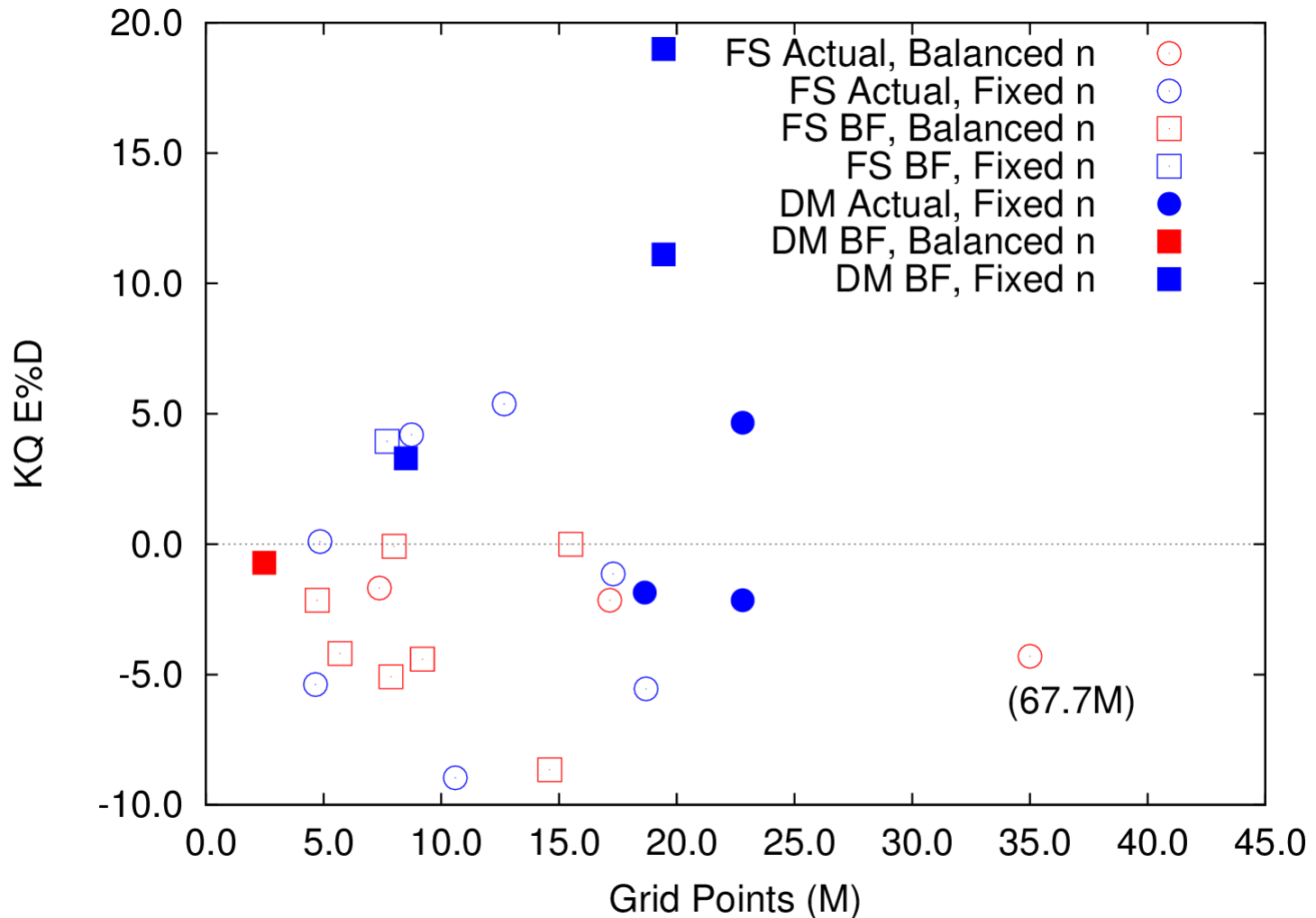
Comparison Error

KT vs Grid Size Case 1.5a

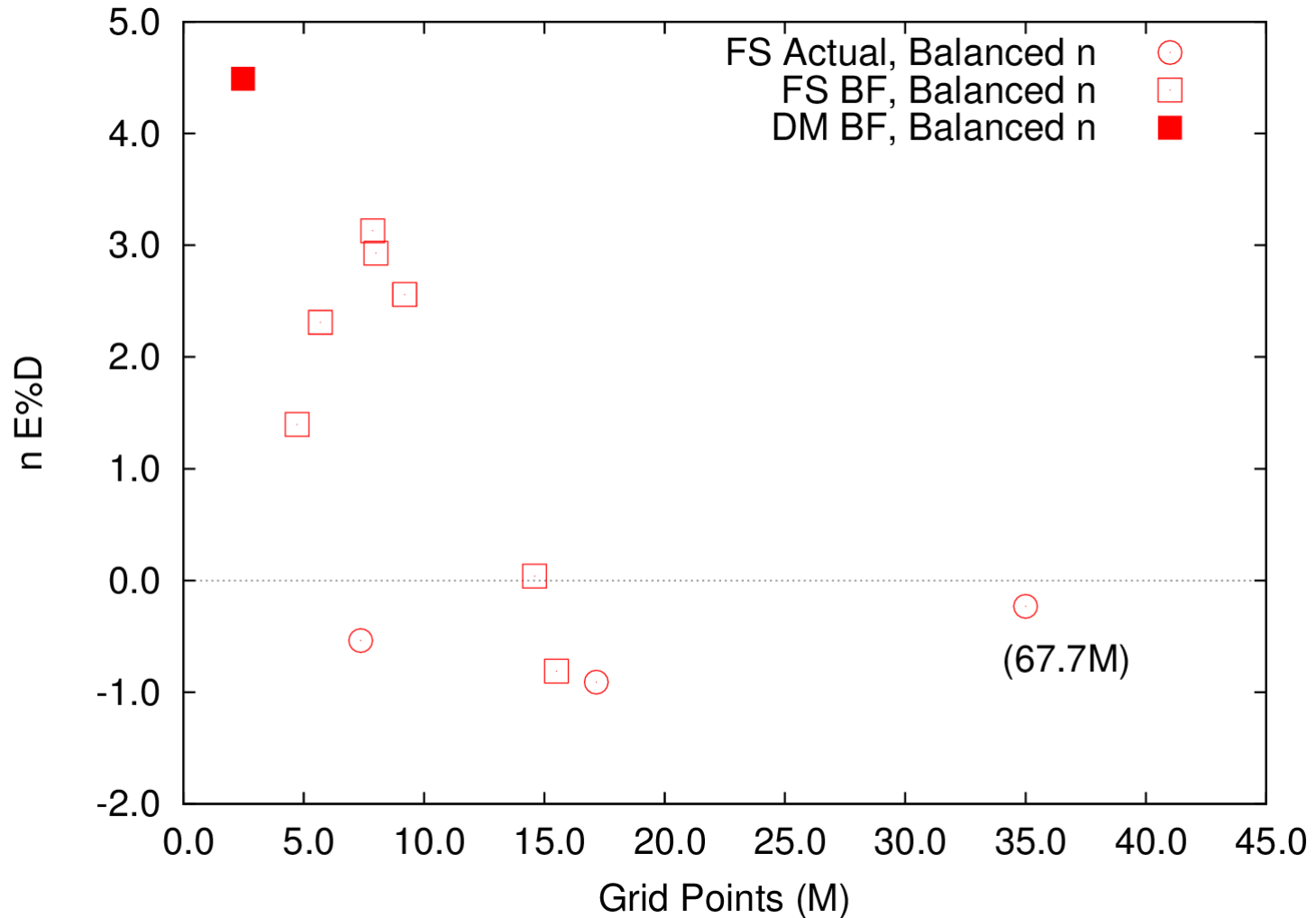


Comparison Error

KQ vs Grid Size Case 1.5a

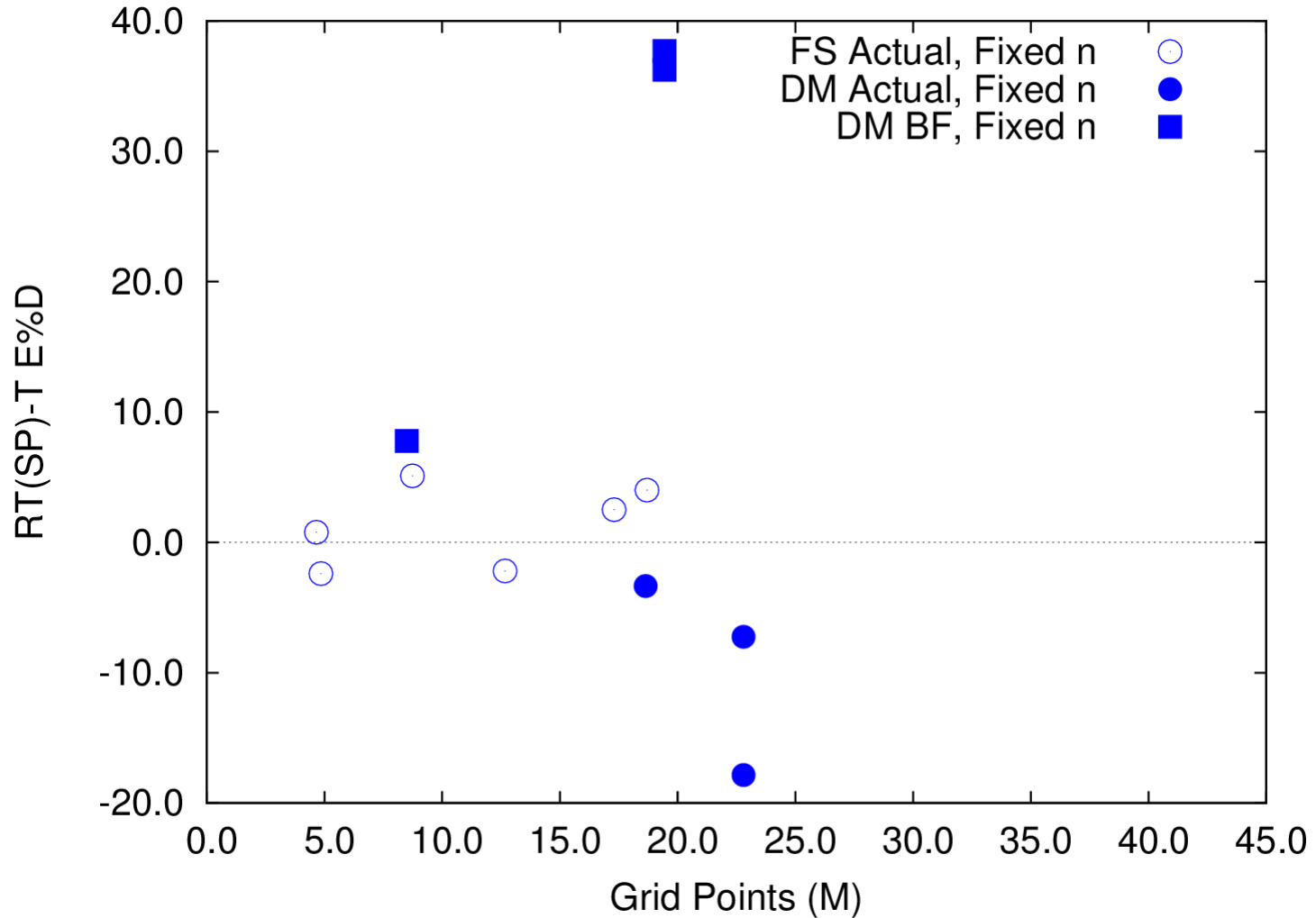


Comparison Error n vs Grid Size Case 1.5a



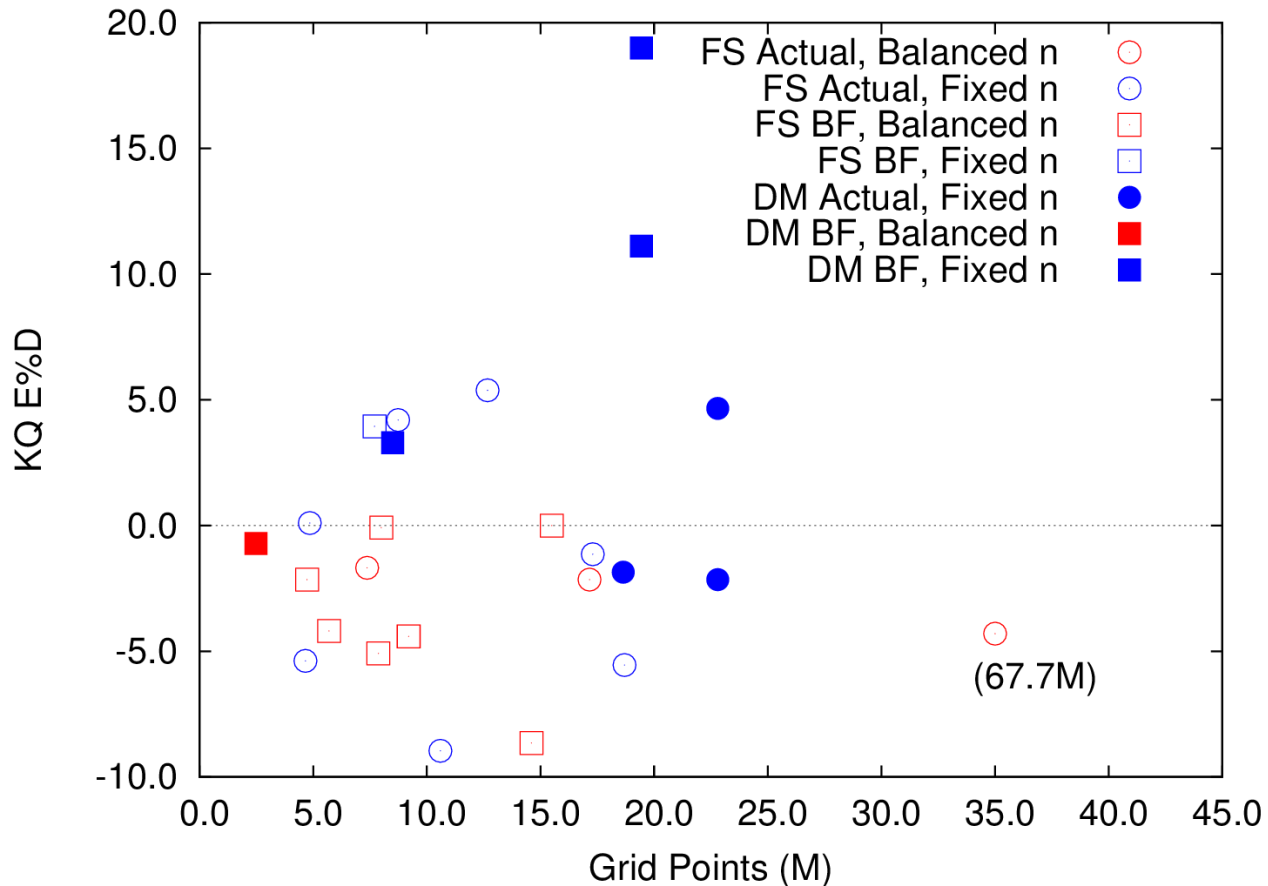
Comparison Error

Rt-T vs Grid Size Case 1.5a



Comparison Error

KQ vs Grid Size Case 1.5a



13 Submissions with Body Force Propeller Model for 1.6a

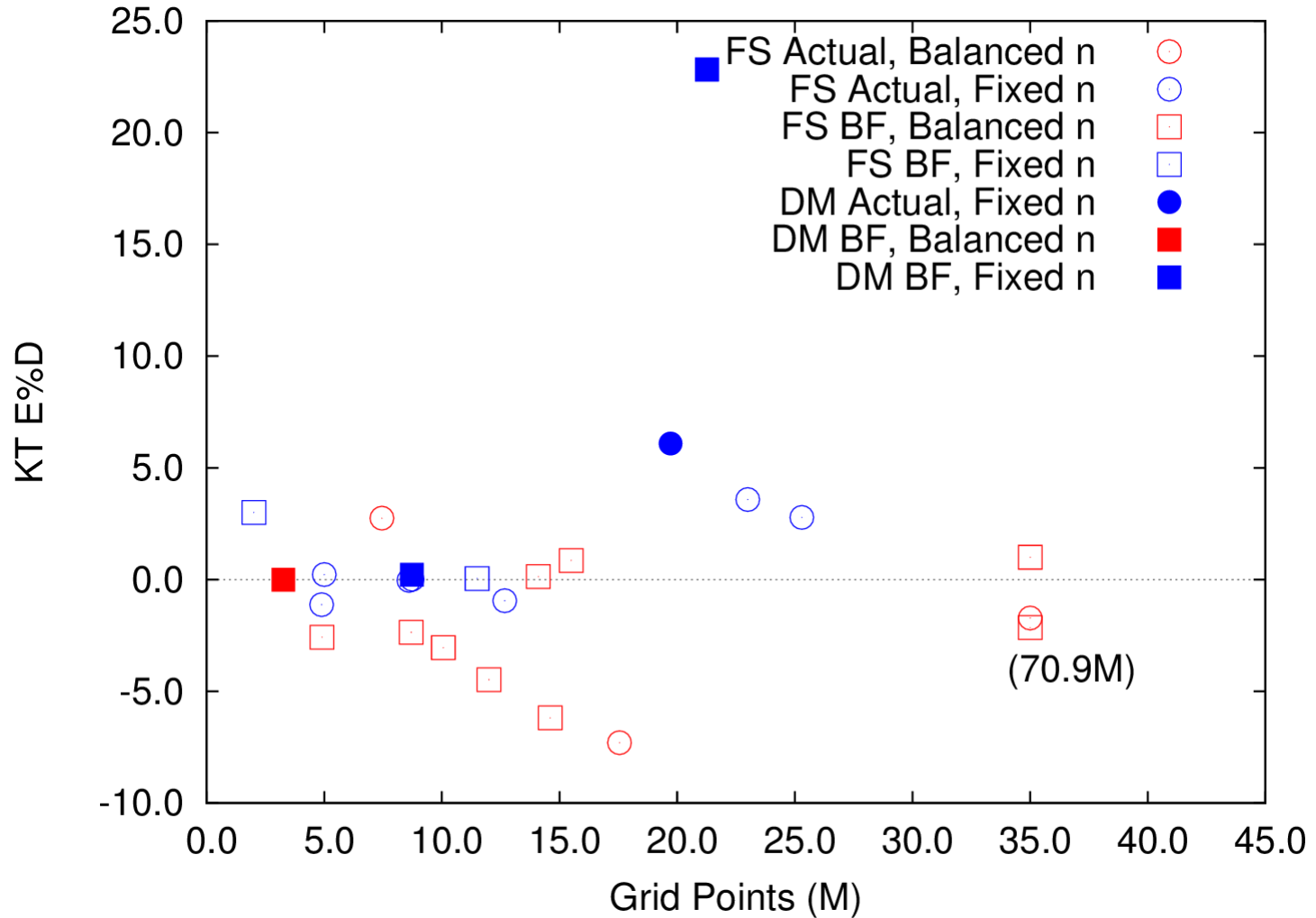
Organization (Code)	Free Surface	Prop. M.		CT	CF	CPV	KT	KQ	n(rps)	RT-T(N)
				x1000	x1000	x1000				
EFD(NMRI)	-	-	D	4.762	-	-	0.233	0.0295	7.5	18.1
CHALMERS-FLOWTECH (SHIPFLOW)	Pot.Flow	BL	S	4.740	3.109	1.632	0.243	0.0292	7.306	-
			E%D	0.450	-	-	-4.480	0.980	2.590	-
CNR/INSEAN (XNAVIS-HO)	LS	BX	S				0.222	0.0300		
			E%D				0.047	-0.017		
ECN/CNRS (ISISCFD/LRN-EASM-AD)	V	BX	S	4.660	3.103	1.563	0.239	0.0306	7.310	-
			E%D	2.140	-	-	-2.360	-3.660	2.530	-
ECN/CNRS (ISISCFD/WF-EASM-AD)	V	BX	S	4.617	3.116	1.501	0.233	0.0305	7.330	-
			E%D	3.040	-	-	0.130	-3.250	2.270	-
HSVA (FreSCo+)	V	BV	S	4.584	3.111	1.473	0.219	0.0272	7.522	-
			E%D	-3.730	-	-	-6.190	-7.640	0.290	-
IIHR (REX-DES)	LS	BS	S	5.158	3.130	2.030	0.238	0.030	7.995	-
			E%D	-8.320	-	-	-2.150	-2.930	-6.600	-
IIHR (REX-RANS)	V	BX	S	4.697	3.180	2.330	0.231	0.031	7.481	-
			E%D	1.360	-	-	1.000	-5.080	0.250	-
MARIC (FINEMarine)	No	BX	S	5.025	-	-	0.240	0.0286	7.500	18.100
			E%D	5.523	-	-	3.005	-3.051	-	
MARIN (ReFreSCo)	LS	BX	S	4.674	3.074	1.619	0.225	0.0291	-	18.392
			E%D	1.857	-	-	3.582	1.462	-	-1.611
PNU (FLUENTv15)	V	BX	S	5.190	3.173	2.017	0.250	0.0300	7.829	18.202
			E%D	-8.988	-	-	-7.296	-1.695	-4.387	-0.564
SHIME (OpenFOAM)	No	BP	S	4.841	3.069	1.772	0.219	0.029	-	20.300
			E%D	-1.669	-	-	6.087	2.240	-	-11.923
SJTU (naoeFOAM)	No	BP	S	4.596	2.548	2.048	0.239	0.0299	7.402	-
			E%D	3.486	-	-	-2.575	-1.356	1.307	-
YNU (SURFv7)	No	BX	S	4.552	3.082	1.470	0.233	0.0294	7.220	-
			E%D	4.410	-	-	0.000	0.340	3.730	-

13 Submissions with Actual Propeller Model for 1.6a

Organization (Code)	Free Surface	Prop. M.		CT	CF	CPV	KT	KQ	n(rps)	RT-T(N)
				x1000	x1000	x1000				
EFD(NMRI)	-	-	D	4.762	-	-	0.233	0.0295	7.5	18.1
ABS (OpenFOAM)	V	A	S	4.786	3.159	1.627	0.227	0.0297	7.673	-
			E%D	-0.497	-	-	2.746	-0.540	-2.303	-
CNR/INSEAN (XNAVIS)	LS	A	S				0.242	0.0337		
			E%D				-0.039	-0.142		
CSSRC (FLUENT)	V	A	S	4.682	3.122	1.560	0.236	0.0302	-	17.257
			E%D	-0.016	-	-	0.014	0.024	-	-0.047
ECN/CNRS (ISISCFD/WF-EASM-RANSE)	V	A	S	4.572	3.133	1.439	0.227	0.0310	-	17.320
			E%D	3.990	-	-	2.780	-3.520	-	4.310
HHI (HiFoam)	V	A	S	4.884	3.254	1.629	0.217	0.0279	-	20.300
			E%D	-2.550	-	-	0.223	5.520	-	-12.280
HHI (STRA-CCM+)	V	A	S	4.758	-	-	0.236	0.0303	-	18.100
			E%D	0.080	-	-	-1.120	-2.710	-	0.280
IIHR (REX-DDES)	LS	A	S	4.731	3.190	1.540	0.237	0.0308	7.430	-
			E%D	0.650	-	-	-1.720	-4.410	0.930	-
KRISO (WAVIS)	V	A	S	4.760	3.204	1.556	0.231	0.0290	7.580	-
			E%D	0.042	-	-	0.858	1.017	-1.067	-
MIJAC (OpenFOAM)	V	A	S	4.523	2.926	1.597	0.233	0.0287	-	16.146
			E%D	5.013	-	-	0.214	2.766	-	10.795
NMRI (NAGISA)	No	A	S	4.893	3.214	1.680	0.240	0.0300	7.440	-
			E%D	-2.760	-	-	-3.050	-1.760	0.760	-
SOTON (OpenFOAM)	V	A	S	4.468	3.196	1.272	0.180	0.0248	-	9.226
			E%D	6.172		-	22.833	15.932	-	49.029
SOTON (STAR-CCM+)	No	A	S	4.468	3.196	1.272	0.180	0.025	-	9.226
			E%D	6.172	-	-	22.833	15.932	-	49.029
UDE (STAR-CCM+)	No	A	S	4.858	3.005	1.862	0.235	0.0280	-	18.900
			E%D	-2.008	-	-	-0.944	5.085	-	-4.420

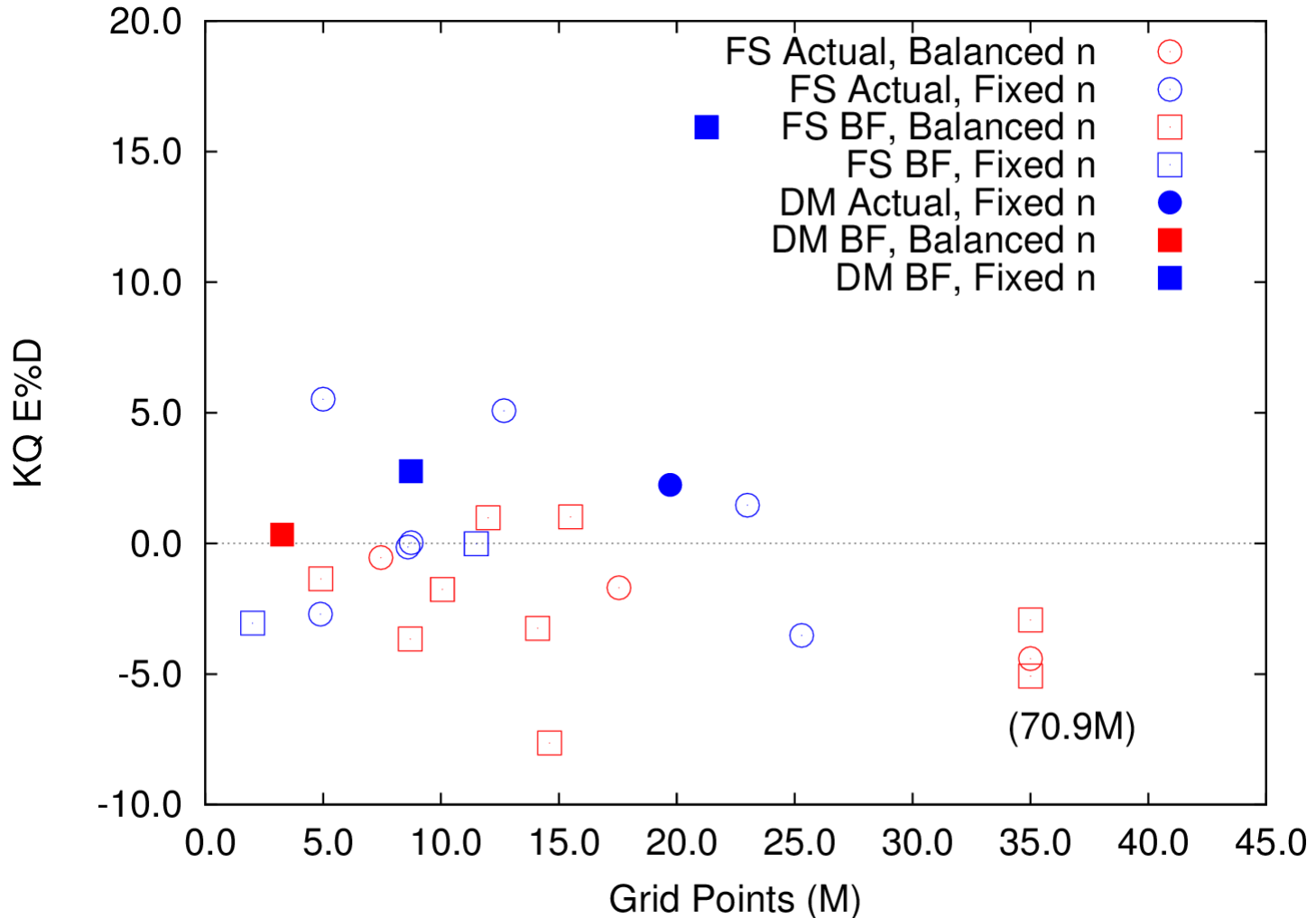
Comparison Error

KT vs Grid Size Case 1.6a

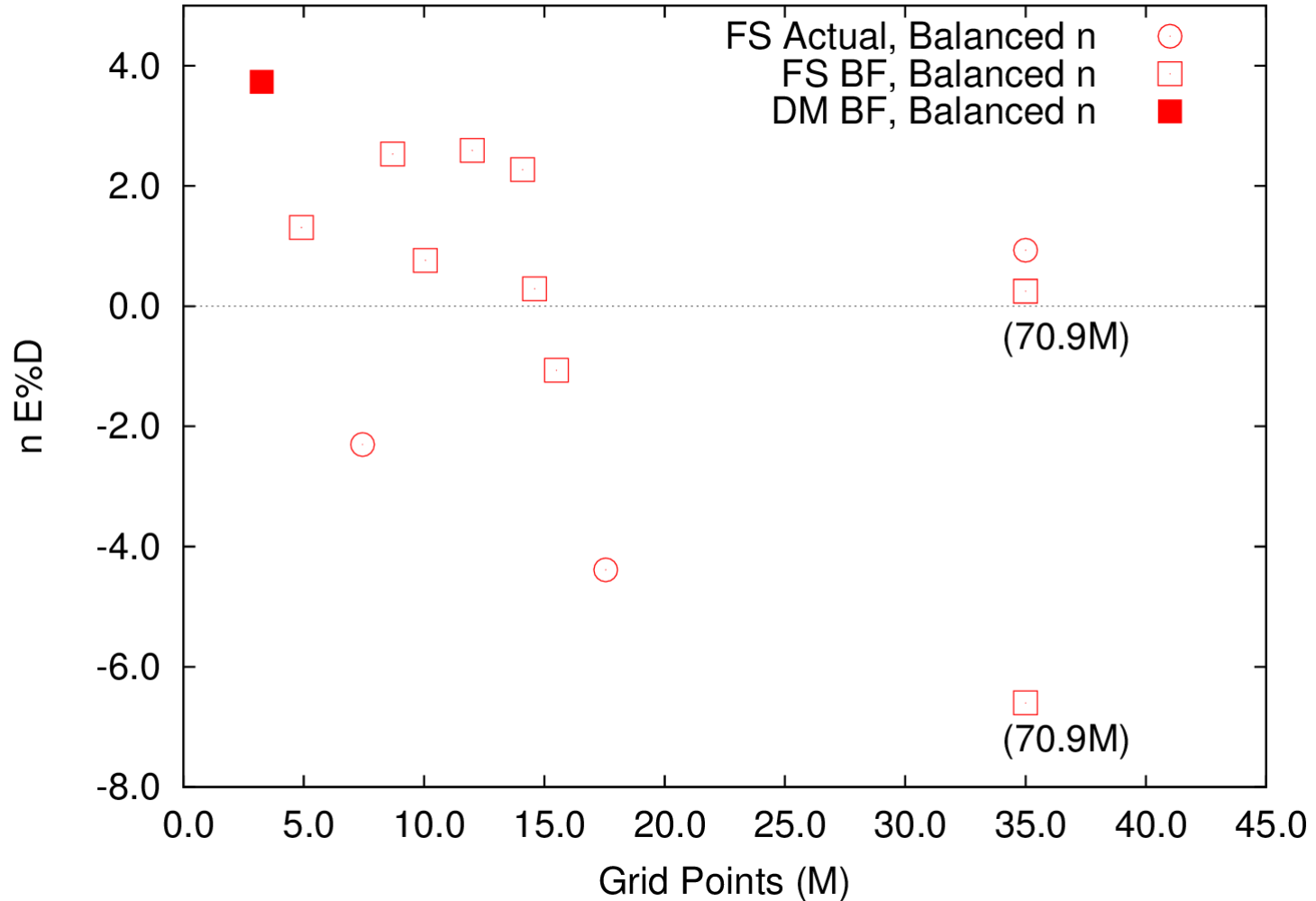


Comparison Error

KQ vs Grid Size Case 1.6a

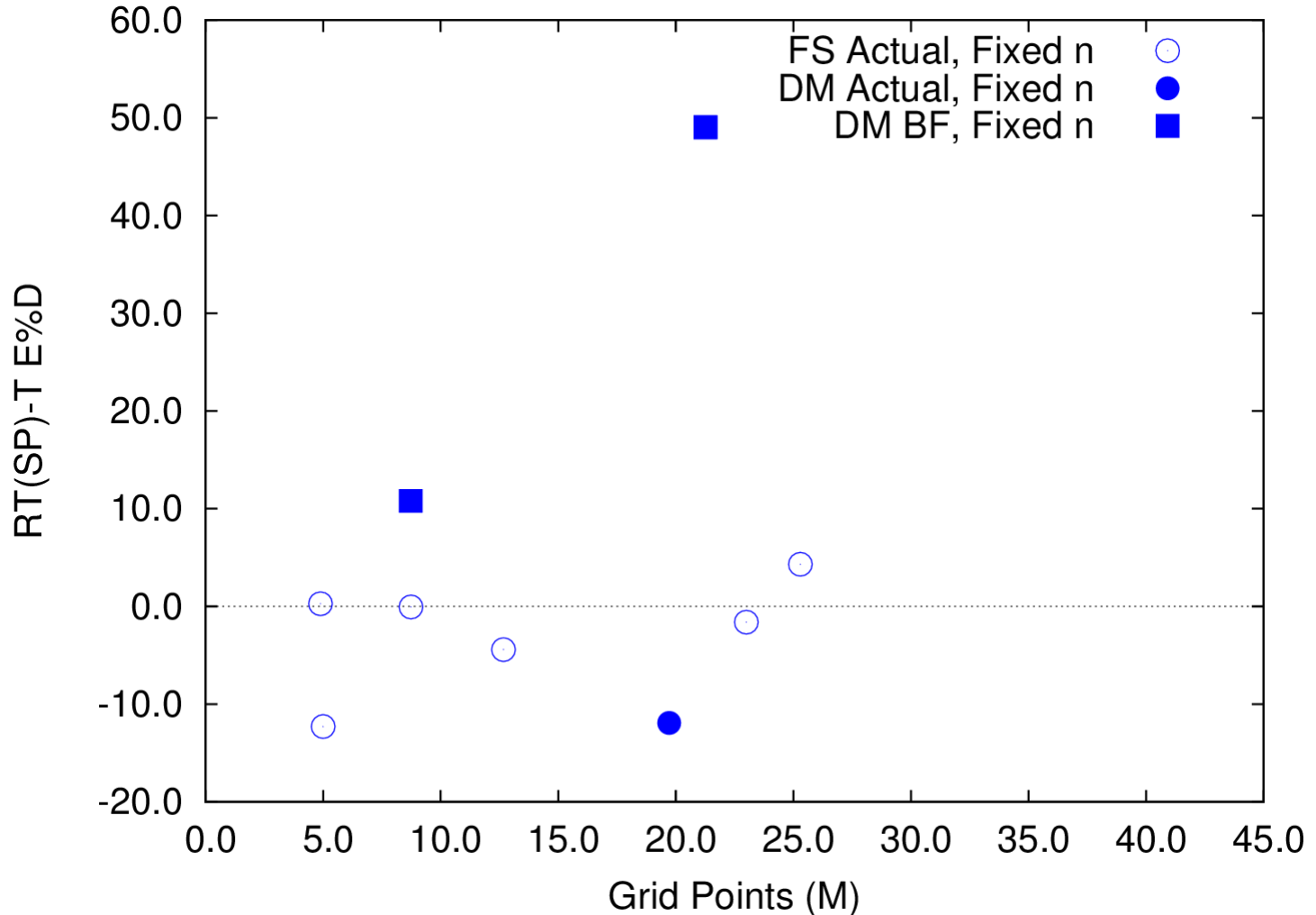


Comparison Error n vs Grid Size Case 1.6a



Comparison Error

Rt-T vs Grid Size Case 1.6a



Case 1.5a Error Statistics

Items	KT			KQ			n			Rt-T		
	E%D mean	E%D mean	stdev	E%D mean	E%D mean	stdev	E%D mean	E%D mean	stdev	E%D mean	E%D mean	stdev
Actual Prop(13/26)	-0.7	2.94	4.48	-1.5	3.65	4.25						
Modeled Prop(13/26)	3.89	6.91	9.9	0.9	4.85	7.32						
force blanc(11/26)	-2.5	3.52	4.51	-3	3.08	2.59	1.3	1.76	1.88			
Fixed (15/26)	4.57	5.95	8.6	1.75	5.13	6.98				4.69	9.78	15.7
All (26)	1.59	4.92	7.88	-0.3	4.25	5.98						

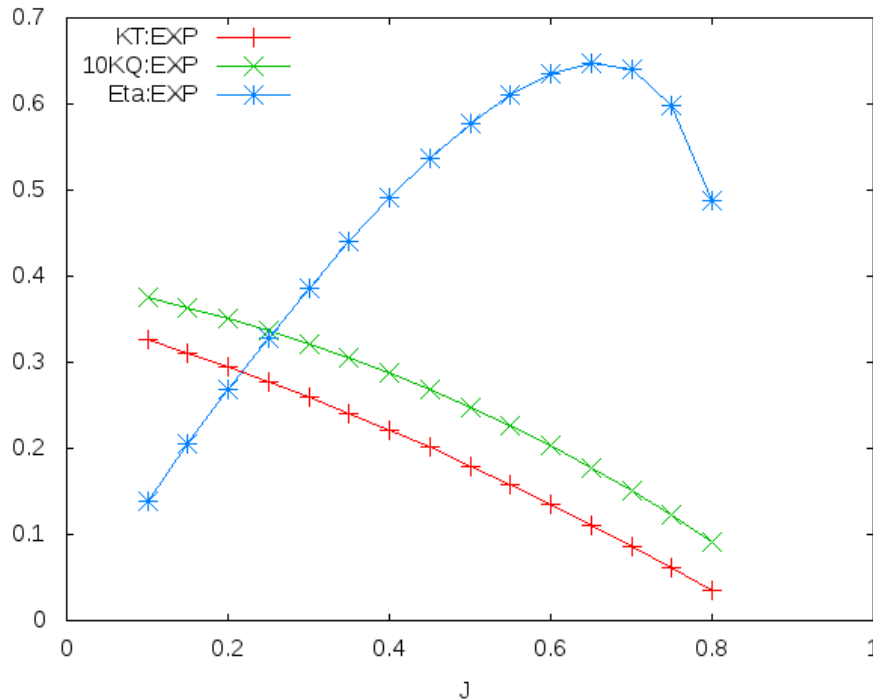
Case 1.6a Error Statistics

Items	KT			KQ			n			Rt-T		
	E%D mean	E%D mean	stdev	E%D mean	E%D mean	stdev	E%D mean	E%D mean	stdev	E%D mean	E%D mean	stdev
Actual Prop(13/26)	-0.7	2.94	4.48	-1.5	3.65	4.25						
Modeled Prop(13/26)	3.89	6.91	9.9	0.9	4.85	7.32						
force blance(11/26)	-1.9	3.07	2.91	-2.3	2.66	2.54	0.02	2.23	2.95			
Fixed (15/26)	4.58	4.9	8.36	3.04	4.49	6.38				7.56	13.1	21.5
All (26)	6.32	8.77	26.2	0.36	3.58	5.47						

Performance of ESD

- Power saving performance of ESD predicted well?
- Power analysis
 - Delivered Power (DP) to Model Propeller at Ship Point
 - No scaling
 - Comparison between w/o duct (case 1.5a) and w duct (case 1.6a)

Powering analysis



Measured Propeller Open Characteristics

- Computed KT, KQ and n
 - Thrust Identity Method $\rightarrow 1-w$ and η_B
 - Thrust T from KT and n
 - $DP = T \cdot (1-w) \cdot U / \eta_B$
- If C_t of Tow condition (Case 1.1a or 1.2a) is available
 - $R_{(tow)}$ from C_t
 - $1-t = (R_{(tow)} - SFC) / T$

Case 1.5a

	1-t	1-w	etar	eta0	DP
EXP	0.812	0.552	1.015	0.501	0.0286
ABS	0.808	0.568	0.984	0.511	0.0296
CHAL	-	0.506	1.044	0.480	0.0262
CSSRC	-	0.532	0.992	0.487	0.0299
ECN	-	0.562	0.963	0.508	0.0299
ECN	0.731	0.565	0.960	0.511	0.0299
ECN	0.797	0.562	0.967	0.508	0.0298
HHI	0.828	0.552	1.015	0.501	0.0287
HHI	0.804	0.530	0.985	0.485	0.0304
HSVA	0.817	0.588	1.070	0.526	0.0262
IIHR	-	0.546	0.979	0.497	0.0301
KRISO	0.805	0.560	1.008	0.504	0.0294
MARIC	0.790	0.515	1.054	0.475	0.0285
MARIN	0.803	0.568	0.987	0.513	0.0289
MIJAC	0.816	0.575	1.024	0.517	0.0277
NMRI	0.829	0.482	1.016	0.462	0.0274
PNU	0.728	0.464	1.078	0.432	0.0300
SHIME	0.773	0.555	1.008	0.504	0.0287
SJTU	0.807	0.528	1.009	0.489	0.0280
SOTON	1.393	0.671	1.000	0.577	0.0254
SOTON	1.471	0.738	1.002	0.610	0.0232
UDE	-	0.559	1.065	0.506	0.0271
ROSTOCK	-	0.559	1.042	0.506	0.0277
ROSTOCK	-	0.501	1.023	0.464	0.0298
YNU	0.795	0.524	1.011	0.499	0.0251

Case 1.6a

	1-t	1-w	etar	eta0	DP
EXP	0.819	0.479	1.009	0.462	0.0269
ABS	0.807	0.510	0.984	0.477	0.0290
CHAL	-	0.434	1.050	0.435	0.0246
CSSRC	-	0.469	0.994	0.454	0.0275
ECN	0.823	0.447	0.990	0.446	0.0258
ECN	0.789	0.468	0.976	0.462	0.0260
ECN	0.787	0.518	0.943	0.477	0.0318
HSVA	0.817	0.526	1.047	0.497	0.0250
IIHR	-	0.461	0.978	0.451	0.0273
KRISO	0.810	0.490	1.020	0.467	0.0273
MARIC	0.815	0.455	1.062	0.443	0.0261
MARIN	0.783	0.505	0.998	0.482	0.0265
MIJAC	0.817	0.479	1.037	0.462	0.0262
NMRI	0.827	0.452	1.013	0.443	0.0267
PNU	0.718	0.440	1.042	0.415	0.0311
SHIME	0.762	0.524	0.982	0.497	0.0265
SJTU	0.811	0.453	1.013	0.446	0.0262
SOTON	1.575	0.645	1.000	0.577	0.0226
SOTON	1.568	0.645	0.992	0.577	0.0228
UDE	-	0.472	1.069	0.457	0.0255
YNU	0.802	0.461	1.012	0.462	0.0239

Summary

Case1.5		1-t	1-w	etar	eta0	DP(KW)
	EXP	0.8116	0.5519	1.0146	0.5014	0.0286
	CFD	0.8702	0.5546	1.0119	0.5030	0.0282
	E%D	-7.2231	-0.4858	0.2664	-0.3219	1.3879
Case1.6		1-t	1-w	etar	eta0	DP(KW)
	EXP	0.8187	0.4786	1.0088	0.4619	0.0269
	CFD	0.8944	0.4926	1.0101	0.4714	0.0264
	E%D	-9.2580	-2.9266	-0.1331	-2.0558	1.7667
Ratio	EXP	1.009	0.867	0.994	0.921	0.940
	CFD	1.028	0.888	0.998	0.937	0.936

Thank you!