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ANY OTHER BUSINESS

Experiences gained on the use of the *Interim guidelines on the second generation intact stability criteria* (MSC.1/Circ.1627) – Calculations for MV Maersk Essen container loss accident

Submitted by Denmark and WSC

SUMMARY

Executive summary:	In accordance with the request in the *Interim guidelines on the second generation intact stability criteria* (MSC.1/Circ.1627) for Member States to use them as complementary measures when applying the requirements of the mandatory criteria of part A of the Intact Stability Code, this document shares the results from calculations made for **MV Maersk Essen**, which lost 750 containers on 16 January 2021.
Strategic direction, if applicable:	Not applicable
Output:	Not applicable
Action to be taken:	Paragraph 18
Related document:	MSC.1/Circ.1627

Background

1 SDC 8 invited Member States to use the *Interim guidelines on the second generation intact stability criteria* (MSC.1/Circ.1627) (Interim guidelines) in practice so as to gain experience with the new calculation methods.

2 After an investigation into the container loss of the containership **MV Maersk Essen** (DMAIB report (2022) "Marine accident report on Maersk Essen's loss of cargo on 16 January 2021") concerns have been raised regarding how the new Interim guidelines will affect containerships in operation today, and whether the measures will improve safety in practice.

3 The results of the calculations made on the **MV Maersk Essen** accident prove that the vessel rolled more than 30 degrees, significantly above the 25-degree failure threshold for Level 2 C2. Furthermore, parametric roll was found to be present, as it was measured using the onboard voyage data recorder, which can be seen in Figure 1.

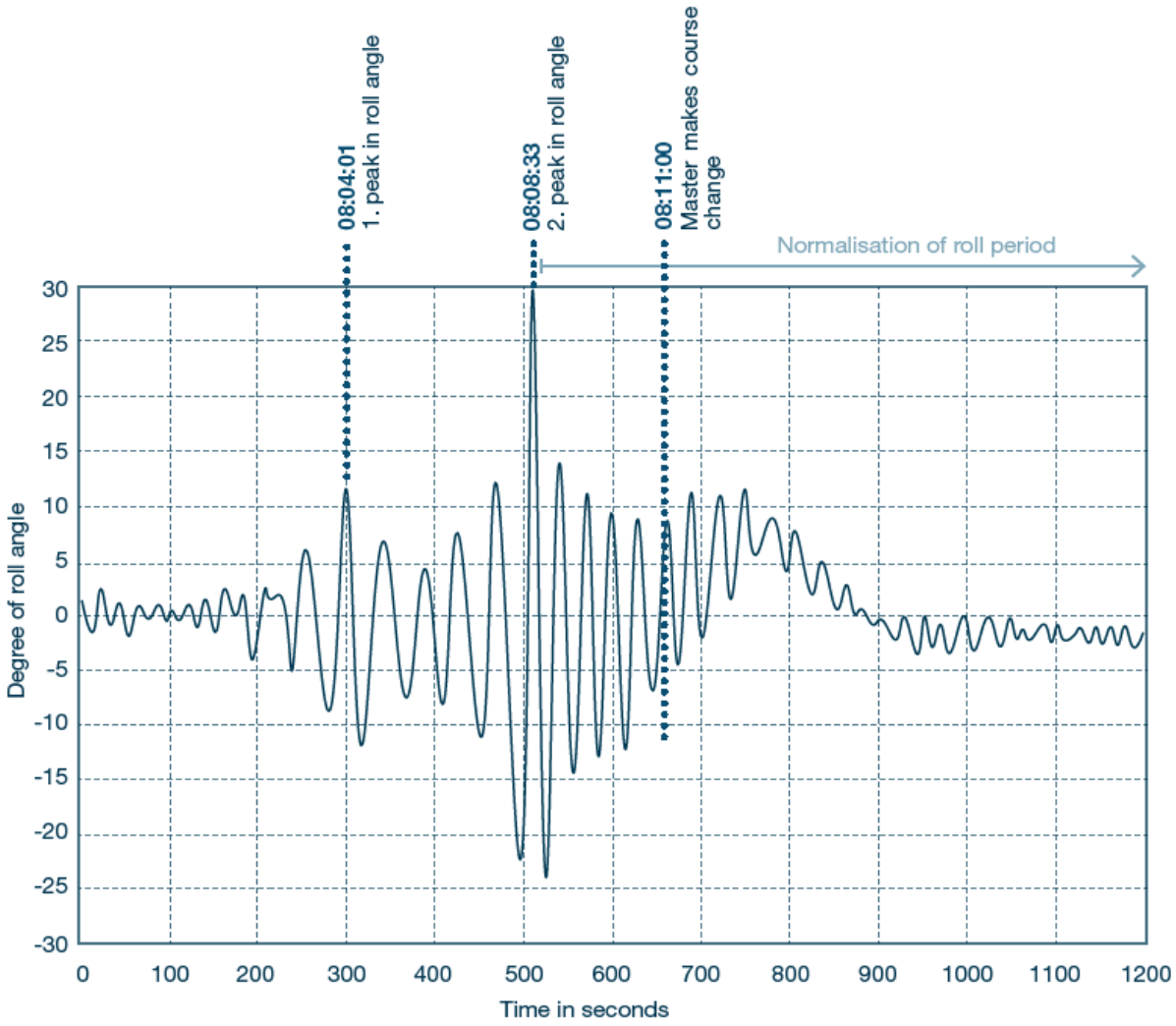

Figure 1. Rolling pattern of MV Maersk Essen on 16 January 2021

4 Calculations were made to check whether **MV Maersk Essen** would pass the MSC.1/Circ.1627 parametric rolling criteria as described in section 2.5 of the Interim guidelines in her loading condition at the time of the accident. One calculation was made using the NAPA software, and a second one was made using American Bureau of Shipping (ABS) in-house software.

5 The results and a high-level comparison of the two calculations are shown in Figure 2,
Figure ***3*** and Figure 4. The two methods led to different assessment results. The 1 degree of freedom (DOF) solver in the NAPA SGIS manager determines a pass condition for Level 2 C2, while the 6-DOF ABS non-linear panel method code results in a failure against the Level 2 C2 criteria.

It is of course important to note that the NAPA calculation is Level 2, while the ABS code tends towards a Level 3 type code. The wave headings and wave scatter used by the ABS code are as follows:

- Wave headings: Only longitudinal waves are used. Head and following waves are considered according to 2.5.3.3 and 2.5.3.4

- Wave scatter table: IACS Rec. No. 34 is used according to 2.7.2.1.2

Software NAPA

Roll damping Simplified Ikeda method (SDC.8/Add.2)

Incident condition

- GM 0.9 m
- T 14 m

Failure mode: Parametric roll

Level 1 Fail

Level 2

- C1 Fail
- C2 OK

T [m]	GM [m]																			
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
6.0	X	X	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
7.0	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
8.0	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
9.0	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
10.0	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
11.0	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
12.0	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
13.0	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
14.0	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
15.0	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
16.0	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure 2. Results of NAPA SGIS Calculation – MV Maersk Essen, Parametric roll failure mode

Ship	TEU	GM (m)	Level 1	C1	C2	R_{PR2}	Level 2
Maersk Essen	13000	0.92	Fail	Fail	0.033	0.025	Fail

Figure 3. Results of ABS SGIS calculation – MV Maersk Essen

Item	NAPA	ABS
Level 2 C2 for unrestricted service	OK	Fail
Software	NAPA SGIS manager	In-house Python code
Roll damping	Simplified Ikeda method	In-house Ikeda method
Ship motion	1-DOF motion solver	6-DOF nonlinear seakeeping panel method

Figure 4. Comparison of calculations done on MV Maersk Essen

6 It should also be noted that the incident of **MV Maersk Essen** occurred in the Pacific, and she experienced significant wave swell heights of 6-8m with very long periods (15-18s). The probability of such waves occurring is not significant (see Figure 6) in the wave scatter data used in MSC.1/Circ.1627, table 2.7.2.1.2, which is taken primarily from the North Atlantic. For a vessel operating on a liner service from North America to China, for example, the wave scatter table is not very representative.

T [m]	GM [m]																			
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
6.0	X	X	X	X	X	X	X	X	X	X	X	OK	OK	OK	OK	OK	OK	OK	OK	OK
7.0	X	X	X	X	X	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
8.0	X	X	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
9.0	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
10.0	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
11.0	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
12.0	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
13.0	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
14.0	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
15.0	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
16.0	X	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure 5. Results of NAPA SGIS Calculation, MV Maersk Essen, Pure loss failure mode

Table 2.7.2.1.2 Wave scatter table

Number of occurrences: 100 000 / T_z (s) = average zero-crossing wave period / H_s (m) = significant wave height																
Tz (s) ► / Hs (m) ▼	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5
0.5	1.3	133.7	865.6	1186.0	634.2	186.3	36.9	5.6	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1.5	0.0	29.3	986.0	4976.0	7738.0	5569.7	2375.7	703.5	160.7	30.5	5.1	0.8	0.1	0.0	0.0	0.0
2.5	0.0	2.2	197.5	2158.8	6230.0	7449.5	4860.4	2066.0	644.5	160.2	33.7	6.3	1.1	0.2	0.0	0.0
3.5	0.0	0.2	34.9	695.5	3226.5	5675.0	5099.1	2838.0	1114.1	337.7	84.3	18.2	3.5	0.6	0.1	0.0
4.5	0.0	0.0	6.0	196.1	1354.3	3288.5	3857.5	2685.5	1275.2	455.1	130.9	31.9	6.9	1.3	0.2	0.0
5.5	0.0	0.0	1.0	51.0	498.4	1602.9	2372.7	2008.3	1126.0	463.6	150.9	41.0	9.7	2.1	0.4	0.1
6.5	0.0	0.0	0.2	12.6	167.0	690.3	1257.9	1268.6	825.9	386.8	140.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7.5	0.0	0.0	0.0	3.0	52.1	270.1	594.4	703.2	524.9	276.7	111.7	36.7	10.2	2.5	0.6	0.1
8.5	0.0	0.0	0.0	0.7	15.4	97.9	255.9	350.6	296.9	174.6	77.6	27.7	8.4	2.2	0.5	0.1
9.5	0.0	0.0	0.0	0.2	4.3	33.2	101.9	159.9	152.2	99.2	48.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10.5	0.0	0.0	0.0	0.0	1.2	10.7	37.9	67.5	71.7	51.5	27.3	11.4	4.0	1.2	0.3	0.1
11.5	0.0	0.0	0.0	0.0	0.3	3.3	13.3	26.6	31.4	24.7	14.2	6.4	2.4	0.7	0.2	0.1
12.5	0.0	0.0	0.0	0.0	0.1	1.0	4.4	9.9	12.8	11.0	6.8	3.3	1.3	0.4	0.1	0.0
13.5	0.0	0.0	0.0	0.0	0.0	0.3	1.4	3.5	5.0	4.6	3.1	1.6	0.7	0.2	0.1	0.0
14.5	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.2	1.8	1.8	1.3	0.7	0.3	0.1	0.0	0.0
15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.6	0.7	0.5	0.3	0.1	0.1	0.0	0.0
16.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0

Figure 6. Wave scatter table used by MSC.1/Circ. 1627. Area highlighted is approximately that experienced by MV Maersk Essen during her container loss

7 Further, it can also be noted that the 25-degree roll angle criteria used in 2.5.3.4 of MSC.1/Circ.1627 is significantly higher than the 19.18 degrees allowed by **MV Maersk Essen'**s loading program, to keep the loads on the lashing system less than their safe working load. Above the lashing roll angle of 19.18, it can be expected that lashings exceed their Safe Working Load (SWL) and begin to approach breaking load (BL). Typically for cargo lashing equipment, there is a factor of safety of 2.0 between BL and SWL, which may explain why the **MV Maersk Essen** rolled more than 30 degrees before a container collapse was experienced. For safe operation, the submitters are of the opinion that exceedance of the SWL should be actively avoided.

8 One conclusion from the investigation of the **MV Maersk Essen** incident was that her inherent stability was high without any deck cargo, and her stability increased as her deck cargo was reduced. It is highly likely that the same situation applies to all large containerships, and it may be an impossible occurrence that such a vessel is lost due to parametric roll as described in MSC.1/Circ. 1627 without first losing significant deck cargo. This loss of deck cargo would contribute to an abrupt improvement of the vessel's stability, preventing further losses or, ultimately the loss of the vessel.

9 Professor Stefan Krüger from the Technical University of Hamburg (TUHH) concluded in his independent investigation into the **MV Maersk Essen** incident that the accident was caused by a combination of vanishing stability on the wave crest and parametric rolling. MSC.1/Circ.1228, section 3.4 acknowledges that various phenomena may occur simultaneously due to the complex nature of the ship response in following or quartering seas. Calculations to check the pure loss failure mode in MSC.1/Circ.1627 returned a pass result using NAPA software at a GM of 1.0m, but a failure at a GM of 0.5m. The results can be seen in
Figure ***5***. MSC.1/Circ.1627 does not require both failure modes to be calculated together.

Discussion

10 The submitters are of the opinion that 6 DOF motion simulation with at least non-linear surge and roll motions is needed as a minimum requirement. It is recommended to consider a similar method to the "E4-Rolls" method used by TUHH as a seakeeping analysis method, for the purposes of assessing the Level 2 C2 criteria. This allows calculations to be performed easily with a large computational effort, due to the Grim's equivalent wave approximation. Details of the method are given in "Operational guidance manual for an Ultra Large Container Vessel in different seaway conditions" Krause (2020).

11 Other 6 DOF non-linear methods like the one used by ABS are also producing reliable results, although these require more computational effort and are Level 3 type calculations. The other alternative would be to decrease the factor $R_{PR2,}$ though this is not preferred when more accurate calculations like the TUHH method are available with a similar level of computational effort.

12 The submitters believe that the purpose of the Interim guidelines is unclear in the case of container ships and request the Sub-Committee to clarify the following: Are the Interim guidelines intended to help avoid loss of deck cargo or are they only intended to address ship survivability?

13 Based on the **MV Maersk Essen** situation, the submitters question the validity of the probabilistic approach / wave scatter data used for Level 2 C2, particularly for container vessels in worldwide operation. As an example, wave statistics based on the North Atlantic are not conservative when operating in areas with very long waves, like the Pacific Ocean. Another example is the speeds used by the Interim guidelines which may not match the vessel's real operational profile. The Sub-Committee is invited to consider the matter with a view to provide clarification.

Proposal for consideration

14 The submitters propose that the Sub-Committee consider whether a comprehensive review of MSC.1/Circ.1627 is needed in order to evaluate the correctness of the calculations for parametric roll analysis, particularly level 2 C2. Large inconsistencies in the results obtained seem to be driven by the different calculation methodologies used in different software. It should not be the case that Level 3 calculations give a "fail" condition while Level 2 calculations show compliance, especially in the case where an incident occurred.

15 The submitters further propose that, for container ships, the criteria for failure in each mode be aligned with the criteria used for container lashing systems in terms of maximum roll angle and transverse accelerations. This measure would provide a framework to prevent cargo loss from vessels, instead of only loss of the ship itself, if the deck cargo is assumed never to be lost. It is also proposed that improved methods for calculating roll period be considered.

16 The submitters also propose that the Sub-Committee consider the conditions under which it is important to consider different failure modes together, instead of separating them.

17 Finally, the submitters propose that the Sub-Committee investigate the reasons why compliance with the interim guidelines can be found also for cases where vessels have lost containers due to parametric roll.

Action requested of the Sub-Committee

18 The Sub-Committee is invited to note the information, in particular the discussion points in paragraphs 10 to 13, and to consider the proposals in paragraphs 14 to 17, and take action, as appropriate.