Common Structural Rules for Bulk Carriers

Proposals for the calculation of the dry bulk cargo's upper surface height

20 May 2009

Revision history

Date	Author	Society	Description
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Overview of the problem

There is a possibility that, for certain combinations of hold geometries and cargo densities, the lower limit of the cargo's upper surface falls below the upper knuckle of the lower stool.

Unfortunately, this is not explicitly considered in the CSR BC documents.

DNV was the first to propose an approach. On this basis, this document provides another formulation, a variation on it and lastly a comparison of the results given by the current formulas in CSR BC and these 3 proposals.

DNV approach

In document "Calculation of Load height – DNV proposal – SESOL – 10th March 2009", the DNV establishes the following formula:

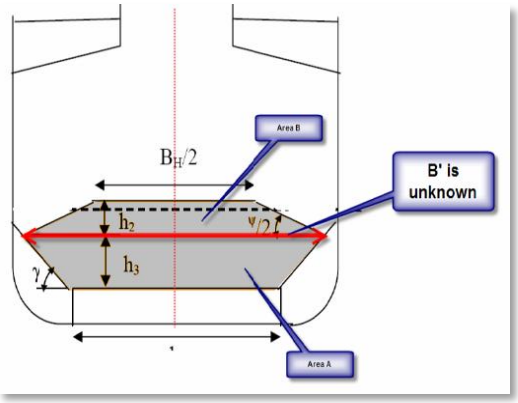

Figure 1: DNV proposal.

with the following assumptions:

- h_3 only to be calculated when h1 is less than 0
- Volume of transverse stools is assumed to be fully considered regardless of shape and height of cargo (Conservative)

The breadth B' is then given by:

$$B_{H.DNV} := \frac{\left(4\cdot\tan(\gamma)\cdot\rho_C\cdot b_{IB}^{\,2}\cdot l_H + \rho_C\cdot b_H^{\,2}\cdot l_H\cdot\tan\left(\frac{\psi}{2}\right) + 16\,\rho_C\cdot V_{TS} + 16\,M\right)^{0.5}}{2\cdot\sqrt{\rho_C}\cdot\sqrt{l_H}\cdot\sqrt{\tan(\gamma)+\tan\left(\frac{\psi}{2}\right)}}$$

BV proposals

First approach

As DNV, it is considered that the breadth of the horizontal part of the cargo's upper surface is $b_H / 2$ and that the volume of the lower transverse stool is fully considered in the calculations.

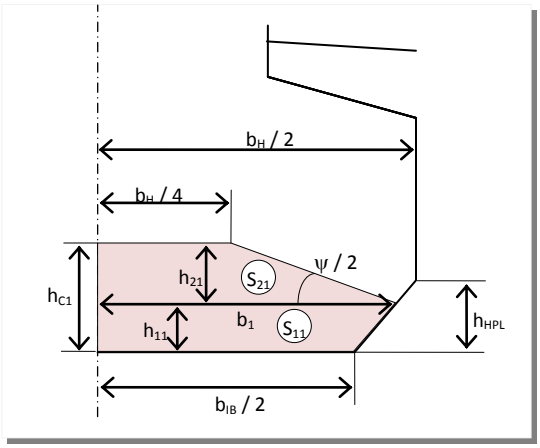

Figure 2: BV first approach.

$$b_1 := \sqrt{\frac{\frac{2}{l_H}\left(\frac{M}{\rho_C} + V_{TS}\right) + \frac{b_{IB}^{\,2}\cdot h_{HPL}}{b_H - b_{IB}} + \frac{1}{8}\cdot b_H^{\,2}\cdot\tan\left(\frac{\psi}{2}\right)}{\frac{h_{HPL}}{b_H - b_{IB}} + \frac{1}{2}\cdot\tan\left(\frac{\psi}{2}\right)}}$$

After some geometric calculations, the breadth b_1 is given by:

In turn, the other values are defined as follow:

$$h_{11} := h_{HPL} \cdot \frac{b_1 - b_{IB}}{b_H - b_{IB}}$$

$$h_{21} := \frac{1}{2} \cdot \left(b_1 - \frac{b_H}{2} \right) \cdot \tan\left(\frac{\psi}{2} \right)$$

And

$$h_{c1} := h_{11} + h_{21}$$

Second approach

Here the assumption is made that the breadth of the horizontal part of the cargo's upper surface is half of the breadth of the cargo's upper surface at its lower corner, i.e. $b_2 / 2$.

Similarly to DNV, the volume of the lower transverse stool is fully considered in the calculations.

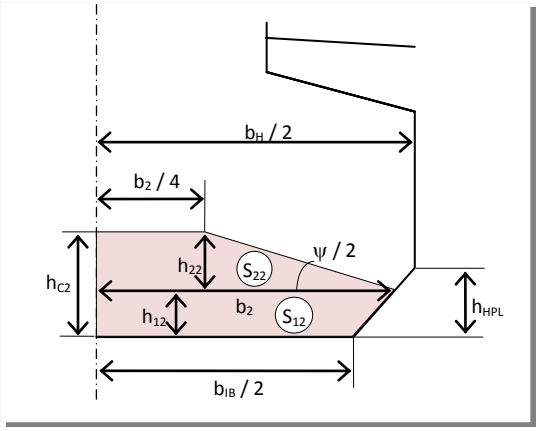

Figure 3: BV second approach.

After some other geometric calculations, the breadth b_1 is given by:

$$b_2 := \sqrt{\frac{\frac{1}{l_H}\left(\frac{M}{\rho_C} + V_{TS}\right) + \frac{1}{2}\frac{h_{HPL} \cdot b_{IB}^2}{b_H - b_{IB}}}{\frac{1}{2}\left(\frac{h_{HPL}}{b_H - b_{IB}} + \frac{3}{8}\tan\left(\frac{\psi}{2}\right)\right)}}$$

In turn, the other values are defined as follow:

$$h_{12} := h_{HPL} \cdot \frac{b_2 - b_{IB}}{b_H - b_{IB}}$$

$$h_{22} := \frac{1}{4} b_2 \cdot \tan\left(\frac{\psi}{2}\right)$$

And

$$h_{c2} := h_{12} + h_{22}$$

Sloped upper surface

The sloped part of the cargo's upper surface is given by the following formulas, provided all the heights given herein have been calculated:

CSR $$z_{CSR}(y) := h_{DB} + h_{HPL} + h_{13} - 2 \cdot \frac{h_{23}}{b_H}\left(2 \cdot y - b_H\right)$$

DNV / BV first approach $$z_{BV1}(y) := h_{DB} + h_{11} + \frac{2 \cdot h_{21}}{b_H - 2 \cdot b_1}\left(2 \cdot y - b_1\right)$$

BV second approach $$z_{BV2}(y) := h_{DB} + h_{12} - 2 \cdot \frac{h_{22}}{b_2}\left(2y - b_2\right)$$

Numerical comparisons

On the basis of the example provided by DNV in its document:

Hold geometry	Length of the hold	l_H	28.80	m
	Breadth of the hold	b_H	32.26	m
	Breadth of the inner bottom	b_{IB}	22.40	m
	Height of the hopper above the inner bottom	h_{HPL}	3.40	m
	Volume of the transverse stool	V_{TS}	187.40	m^3
Cargo description	Total mass in the cargo hold	W	8000.00	t
	Density of the cargo	ρ	3.00	t/m^3
	Angle of repose of the cargo	ψ	35.00	°

The following sets of values have been calculated:

Description	Variable	CSR BC	BV 1	BV2	DNV
Breadth of the cargo upper surface at the point of contact with the hopper	B' ; b_1 ; b_2	32.6000 m	28.6428 m	28.3136 m	28.6431 m
	h_0	3.4000 m			
	h_1	-1.7157 m	2.1527 m	2.0392 m	2.1526 m
	h_2	2.5429 m	1.9726 m	2.2318 m	1.9727 m
Height of the horizontal part of the cargo upper surface	h_C	4.2272 m	4.1253 m	4.2710 m	4.1253 m
Height of the upper surface at b_H / 4	z(b_H / 4)	4.2272 m	4.1253 m	3.9599 m	4.1253 m
Variations of h_C	/CSR		-2.41 %	+1.04 %	-2.41 %
	/BV1			+3.53 %	0.00 %
	/BV2				-3.53 %
Variation of B' ; b_1 ; b_2	/CSR		-12.14 %	-13.15 %	-12.14 %
	/BV1			-1.15 %	0.00 %
	/BV2				+1.15 %
Variation of z(b_H / 4)	/CSR		-2.41 %	-6.32 %	-2.41 %
	/BV1			-4.01 %	0.00 %

Verifications have been made by calculating the corresponding mass of cargo on the basis of the volume used by the cargo and its density. In each case, the initial value of 8000 t is obtained.

The following figure gives the different shapes of the cargo's upper surfaces.

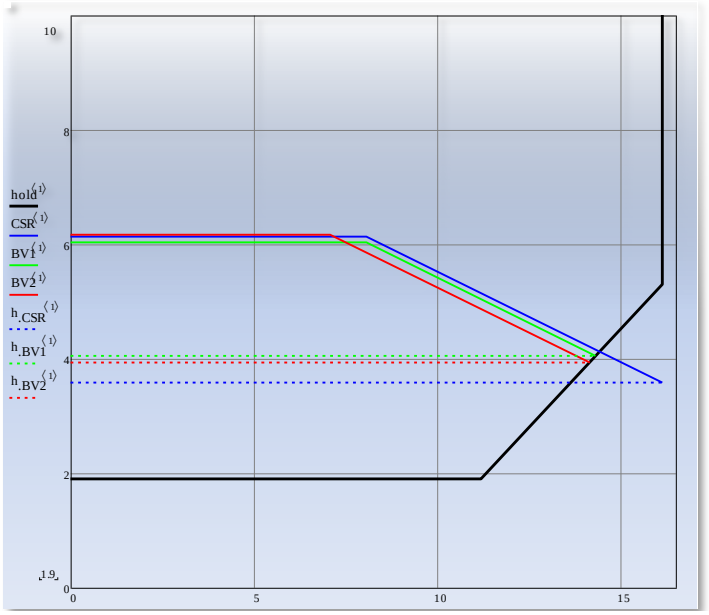

Figure 4: shapes of the cargo's upper surface.

Conclusion

The above values show that:

- DNV approach and BV first approach give the same results; the difference is only on the variables used in the formulas.
- The volume of the cargo is correctly given by the CSR formulation even for this kind of configuration.
- Regarding the differences between these 4 approaches:
  - All the horizontal parts of the cargo's upper surfaces are close from each others.
    Considering all the approximations already made for modelling the shape of the cargo, these differences are not significant;
  - The sloped parts of the cargo's upper surfaces have the same inclination.
    Hence, the only largest difference is between the current CSR approach and the second proposal made by BV, due to the difference in breadth of the horizontal part of the cargo's upper surface.
    However, these differences remain small and can be neglected;
  - The breadth of the hold submitted to the cargo load is significantly reduced in each of the 3 new propositions.

As the loads (dry bulk cargo pressure, inertial pressure, shear load…) are linear functions of the cargo height, the consequences of these differences are also limited.

The first intent of this proposal (DNV, BV1 and BV2 approaches) is to have a better description of the space used by the cargo in the hold.

The first drawback of these alternative proposals is the reduction of the breadth of the hold submitted to the cargo load compared to the current CSR BC approach.

The second drawback is the increase in the complexity of the rules for that part as it is needed to make the difference between the cases where the hold is filled above the hopper and those where the hopper is not fully covered by the cargo.

As the difference in the cargo height are not significant but as the impacted breadth of the hold is lesser with the new approach, it is more conservative and simpler to keep the CSR BC as they are.

However, it could be of interest to benefit of the forthcoming harmonisation for improving the bulk load approach.