Germanischer Lloyd

# Consideration of Appendages for Roll Damping in the Weather Criterion

**Tobias Zorn, Vladimir Shigunov, Boris Altmayer**

2013-09-23

# Contents

# The Weather Criterion (2/2)

- Roll-back angle due to wave action:

$$\varphi 1 = 109 * k * X1 * X2 * \sqrt{r * s} \ [°]$$

Empirical formula based on results from a ships built or planned before 1977.

factor k depends on

$$\frac{Ak*100}{LWL*B}; \text{ with Ak} = \text{bilge keel area}$$

| $\frac{A_k \times 100}{L_{WL} \times B}$ | $k$ |
|---|---|
| 0 | 1.0 |
| 1.0 | 0.98 |
| 1.5 | 0.95 |
| 2.0 | 0.88 |
| 2.5 | 0.79 |
| 3.0 | 0.74 |
| 3.5 | 0.72 |
| $\geq 4.0$ | 0.70 |

# What Appendages Contribute to $A_k$?

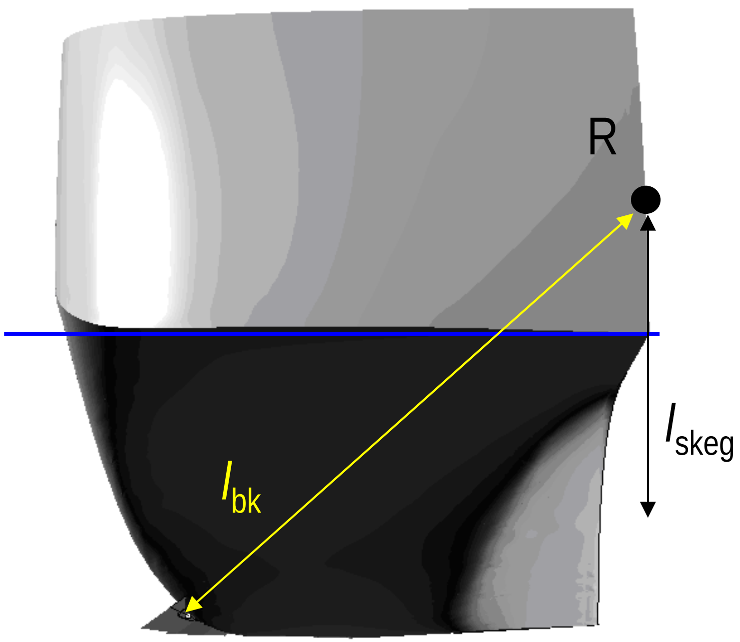
- Uncertainty within the community of naval architects about constructional elements to be considered in the calculation of $A_k$
- IS Code: *total overall area of bilge keels, or area of the lateral projection of the bar keel, or sum of these areas*
- Other appendages, such as centerline keels, skegs, rudder etc. also contribute to damping, so it seems reasonable to include them into $A_k$
- Whether or not to include, depends on the design and approval practice; question:
  - how different hydrodynamic characteristics of different appendages should be taken into account when $A_k$ is calculated

# Example: Central Skeg

- First, to take into account the difference in the lever between the skeg and bilge keel, the "equivalent" bilge keel area was calculated as

$$A_{\text{bk}} = A_{\text{skeg}} l_{\text{skeg}} / l_{\text{bk}}$$

  where $A_{bk}$ = area of the „equivalent" bilge keel, $l_{skeg}$ = lever of skeg and $l_{bk}$ = lever of bilge keel
- This reduces the "equivalent" bilge keel area by about 48% of the projected skeg area
- Second, how difference in hydrodynamics can be taken into account?



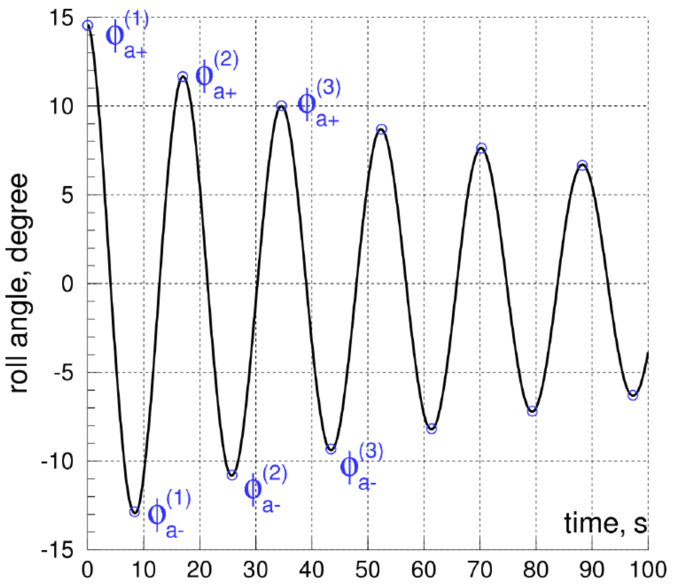
# Central Skeg: Roll Decay Simulations

- RANSE-CFD simulation of roll decay test
- Post-processing: logarithmic decrement

$$\ln\delta = \ln\frac{\phi_{a+}^{(i)}}{\phi_{a+}^{(i+1)}} \text{ vs. } \phi_{a-}^{(i)} \text{ and } \ln\frac{\phi_{a+}^{(i)}}{\phi_{a-}^{(i+1)}} \text{ vs. } \phi_{a+}^{(i+1)}$$

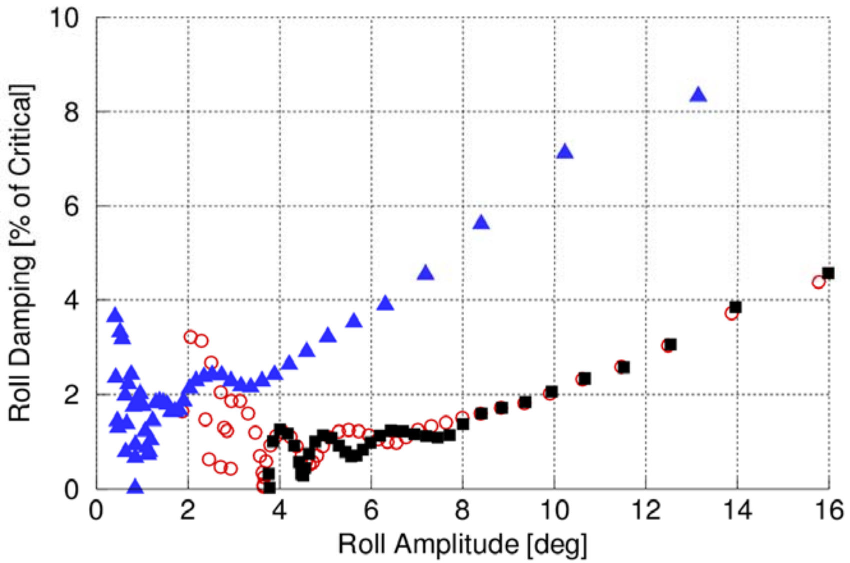
and damping as percentage of critical damping:

$$\zeta_{\%} = \frac{\ln\delta}{2\pi}100\%$$



# Central Skeg: Results

- Skeg does not add any distinguishable roll damping compared to the bare hull
- whereas the bilge keel with the reduced “equivalent” area increases roll damping sufficiently
- Thus, skeg area cannot be taken completely into $A_k$
- Approval should be done on case-by-case basis




Roll damping as percentage of critical damping for bare hull (○), hull with skeg (■) and hull with “equivalent” bilge keel (▲)

# Scale Effects: Introduction (1)

- For ships with parameters outside of applicability limits of weather criterion, MSC.1/Circ.1200 (Interim Guidelines for Alternative Assessment of the Weather Criterion) can be used alternatively
- The *standard alternative procedure* is to define roll-back angle in regular waves $\phi_{1r} \Rightarrow$ no correction for scale effect is possible
- Because direct measurement may require very steep to breaking waves, two alternative methodologies can be used:
  - *three-step methodology* (roll damping defined from roll decay tests or forced roll tests)
  - *parameter-fitting methodology* (customised tests to fine-tune parameters of numerical model, including damping)

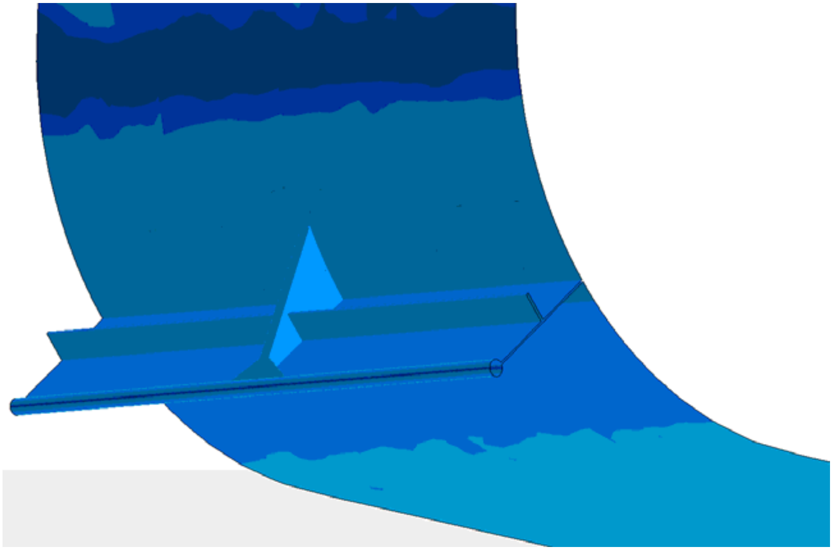
  $\Rightarrow$ Both alternative methodologies allow for correction for scale effects: roll damping due to frictional forces on hull can be reduced
- However, none of the procedures considers scale effects for bilge keels

# Scale Effects: Introduction (2)

- To reduce scale effect of roll damping due to bilge keels, their breadth should be in model scale greater than 7.0 mm
- In some cases, bilge keels are made deeper than those in full-scale ship to minimise scale effects
- The assumption is that *bilge keels are less efficient in model scale* than in full scale due to relatively larger thickness of boundary layer in model scale
- In the present study, this assumption is checked using RANSE-CFD simulations for an FPSO at zero forward speed for three scales:
  - 1/1 (full scale)
  - 1/85 (model scale)
  - 1/50 (model scale)

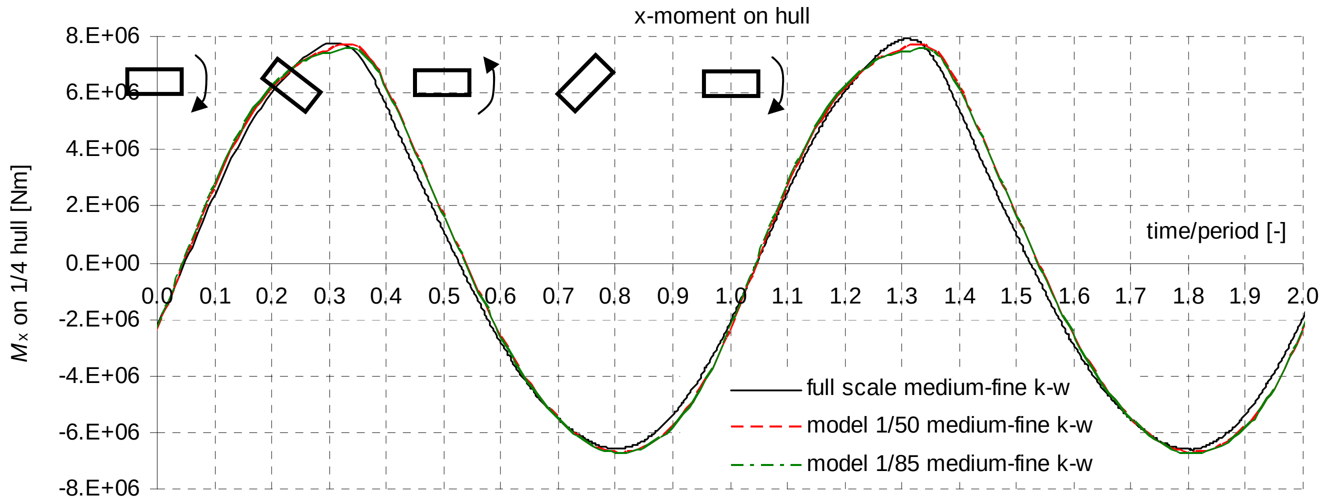
# Scale Effects: Solution

- To reduce computational effort, 1 m-long cylindical section of the hull was used
- *k*-$\omega$ turbulence model without wall functions was used
- Free surface was not modelled
- Roll motion with 10°-amplitude was imposed; total moment *M*x with respect to rotation axis was computed
- Inertial part of total moment was computed by Fourier transform and subtracted to derive roll-damping part

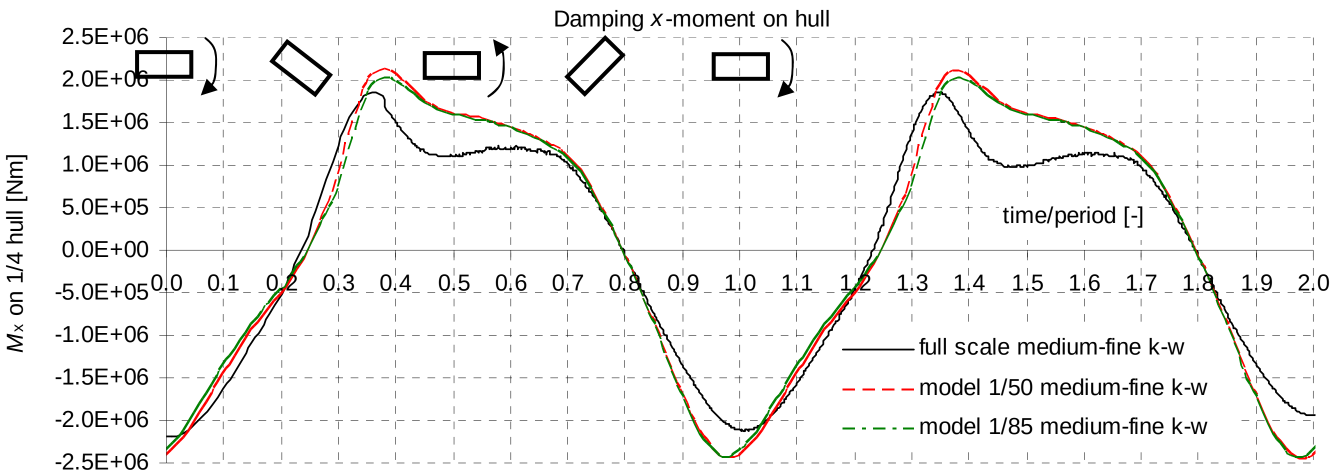


Geometry

# Scale Effects: Moment on Hull
## (no integration over bilge keel)

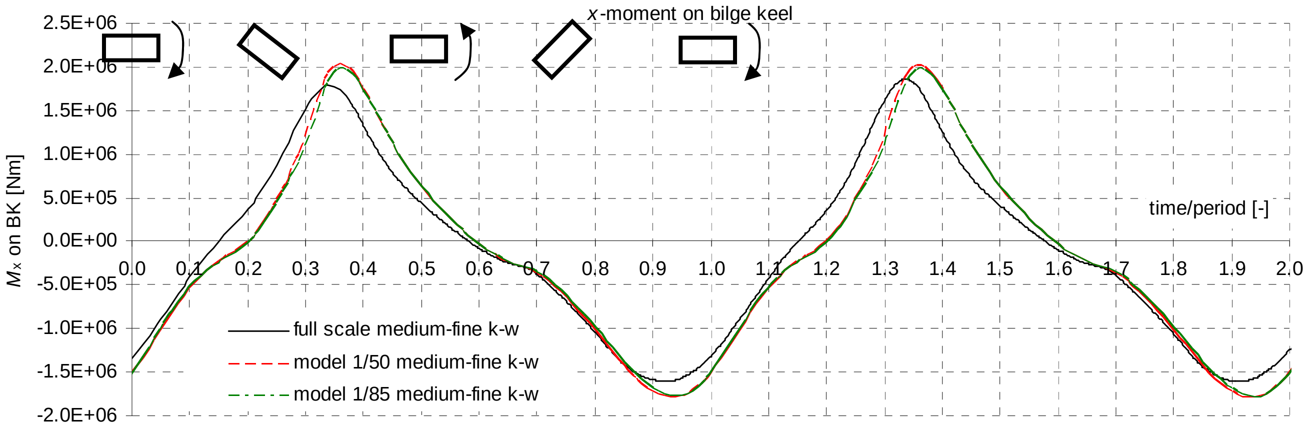



Total moment on hull with respect to *x*-axis vs. time for different scales

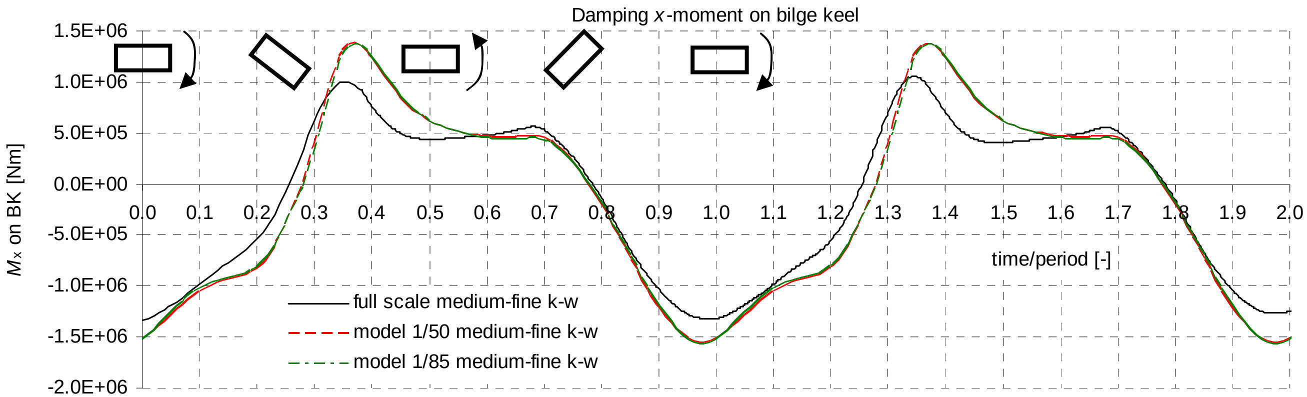



Damping part of the moment on hull with respect to *x*-axis vs. time for different scales

# Scale Effects: Moment on Bilge Keel alone




Total moment on bilge keel with respect to *x*-axis vs. time for different scales




Damping part of the moment on bilge keel with respect to *x*-axis vs. time for different scales

# Scale Effects: Conclusions

- Damping contributions from bilge keel are in this case substantially larger in the model scale than in the full scale
- Reason: the influence of viscosity and vortex separation is more significant in the model scale than in full scale

| Scale | Equivalent linear roll damping of bilge keel, N·m·s/rad | Equivalent linear roll damping of bilge keel, % deviation from reference |
|---|---|---|
| full scale | $3.017 \cdot 10^8$ | 0.0 |
| model 1/50 | $3.667 \cdot 10^8$ | 21.5 |
| model 1/85 | $3.622 \cdot 10^8$ | 20.0 |

Thank you for your attention.

Questions?

Contact:

vladimir.shigunov@gl-group.com