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SEAKEEPING PERFORMANCES OF AN AHTS SHIP

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ABSTRACT

The importance of the evaluations of the response amplitude operators as well as of the accelerations in several points of interest on board of ship is directly linked to the index of operation of a floating structure. The higher the sea state to operate, the better the ship efficiency and operability. The aim of the present paper is to underline the importance of the evaluation of seakeeping performances of an AHTS ship in order to evaluate the upper limits of the affordable sea states from the point of view of roll the motions amplitudes and the comfort on board. The effects of bilge keel on roll motions are also investigated.
*The paper is dedicated to the memory of our **Prof. Dr. Eng. Ion Bidoae**, pioneer in ship hydrodynamics research and education in Romania, who passed away 20 years ago.*

Keywords: *seakeeping, bilge keel, comfort on board, accelerations*

1. INTRODUCTION

The purpose of the hydrodynamic analysis is to perform the calculations in order to evaluate ship motions and accelerations in several points of interest in order to be compared with specific requirements in offshore industry [7].

The evaluation has been performed using a computer code based on the well-known theory developed by Salvesen, Tuck and Faltinsen [6]. The program is able to calculate the response amplitude operators (RAO) and phases for all six degrees of freedom, i.e. surge, sway, heave, roll, pitch and yaw motions. The main assumptions of the program refer to the nature of the fluid, considered to be inviscid, the ship geometry allowing the assumption that the length is much larger than the beam and draft and the displacements of the ship and the waves are small. In other words, the slender body theory is assumed and the three dimensional hydrodynamic quantities are expressed in terms of solution to the sectional two-dimensional problem of a cylinder with the same shape as the individual cross-sections oscillating on the free surface [5]. The program is using the "close fit source distribution technique" developed by Frank. The nonlinear roll damping is introduced using Tanaka method.

Based on the first set of results the calculations of the accelerations have been also performed in all defined points of interest for different sea states, using a specific computer code, ACCEL. Using the RAO's and the JONSWAP formulation of the sea spectrum, statistic calculations can be performed. The coordinate system is presented in Fig. 1.

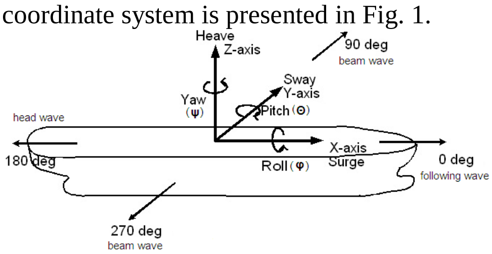

Fig. 1. Motions and coordinate system

2. GENERAL INPUT DATA

The application was carried out for an anchor handling tug supply (AHTS) having the main characteristics according to Table 1.

Table 1. Main characteristics of the ship

Length between perpendiculars, L_{PP}	59.40 m
Breath, B	16.00 m
Design draught, T	4.80 m
Displacement	3277.30 t
Vertical center of gravity, KG	6.11 m
Metacentric height, GM_T	1.74 m

Photo 1. General view of the ship

The spectral analysis was performed for two sea states (fully arisen sea) i.e. Sea State 4 and Sea State 8 respectively.
For the sea state 4:
- wind speed, V_w = 10.3 m/s,
- average wave height, h_w = 1.52 m,
- significant wave height, $h_{1/3}$ = 2.32 m,
- significant wave period, $(T_w)_{1/3}$ = 6.38 s.

For the sea state 8:
- wind speed, V_w = 23.7 m/s,
- average of wave height, h_w = 6.35 m,
- significant wave height, $h_{1/3}$ = 10.13 m,
- significant wave period, $(T_w)_{1/3}$ = 9.55s.

The calculations have been carried out for a range of heading angles from 0º (following sea) up to 180º (head sea), with a step of 15º.
The accelerations have been evaluated in 4 different locations (points), having the following coordinates related to zero station (aft perpendicular) K0, centre line, CL and base line, BL respectively:
- P1 (-3.475 m; 0.000 m; 6.300 m) – Stern roller axis;
- P2 (28.8 m; 6.800 m; 6.800 m) – Midship section on deck, starboard;
- P3 (58.300 m; 0.000 m; 11.750 m) – Deck, fore perpendicular (FP);
- P4 (45.100 m; 6.300 m; 14.200 m) – Navigation deck, starboard.

All evaluations have been performed for zero speed and for v = 12 kts.

3. EVALUATION OF MOTIONS

The results of the calculations are graphically presented in terms of response amplitude operators for the two speeds: zero (Fr = 0) and v = 12 kts. The zero speed is considered the most important one as well as it corresponds to the operational case in open sea. For the first case the results are Fig. 2 ÷ Fig 10 and for the second case in Fig. 5 ÷ Fig 10 for v = 12 kts.

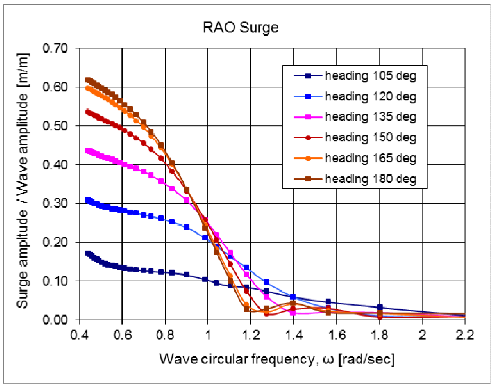

Fig. 2. RAO’s surge motion (v = 0)

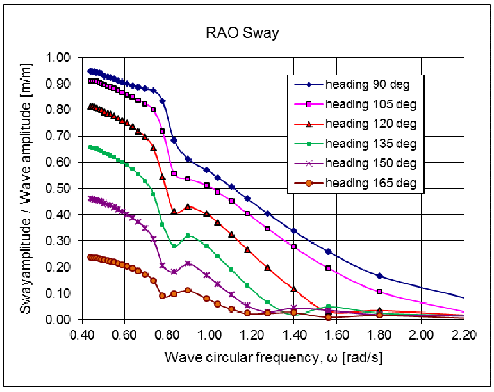

Fig. 3. RAO’s sway motion (v = 0)

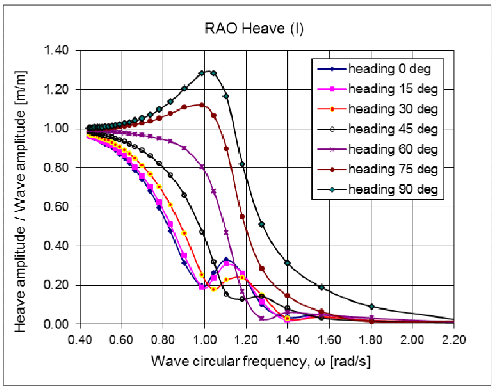

Fig.4. RAO's (I) heave motion (v = 0)

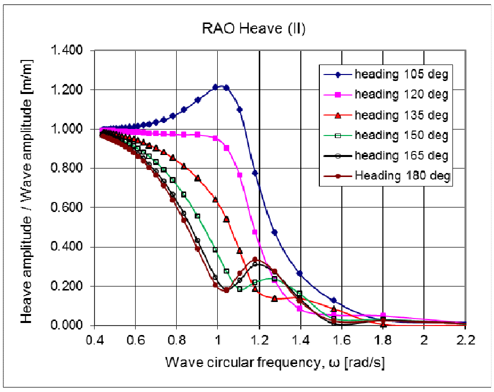

Fig. 5. RAO's (II) heave motion (v = 0)

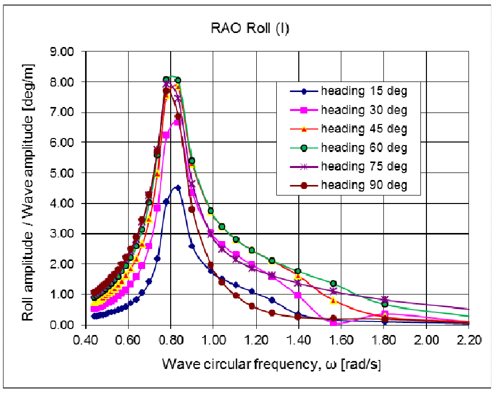

Fig. 6. RAO's (I) roll motion (v = 0)

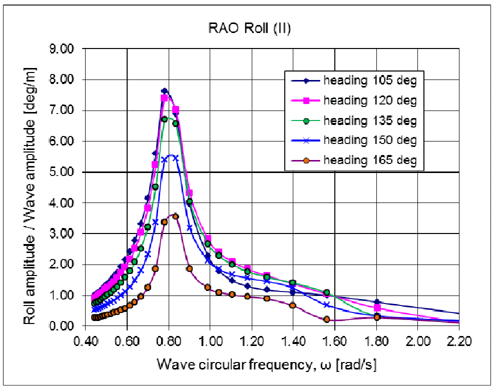

Fig. 7. RAO's (II) roll motion (v = 0)

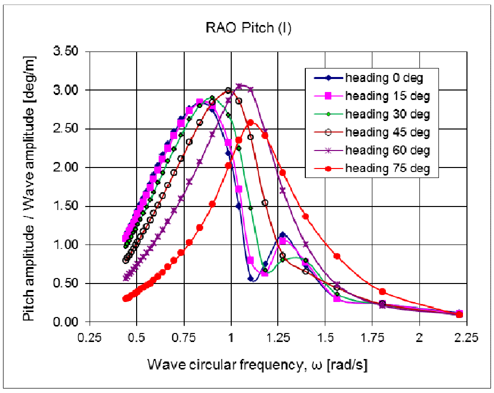

Fig. 8. RAO's (I) pitch motion (v = 0)

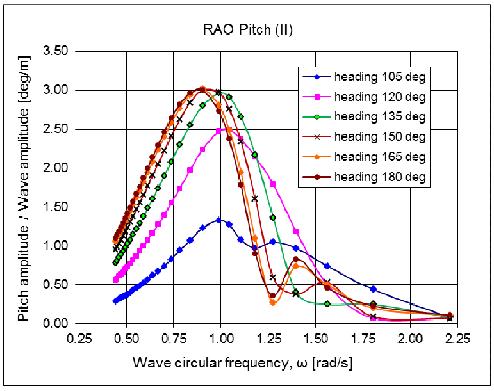

Fig. 9. RAO's (II) pitch motion (v = 0)

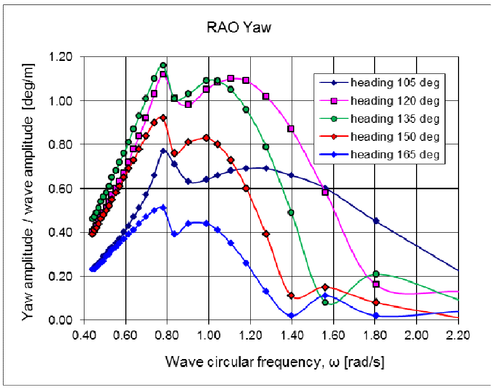

Fig. 10. RAO's yaw motion

For zero speed, due to their higher impact on accelerations, for heave, roll and pitch motions, the results are presented for the whole range of frequencies used for calculations which include the case related to following waves cases [2], [4].

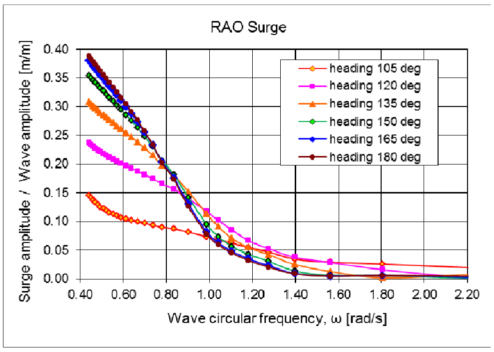

Fig. 11. RAO's surge motion (v = 12 kts)

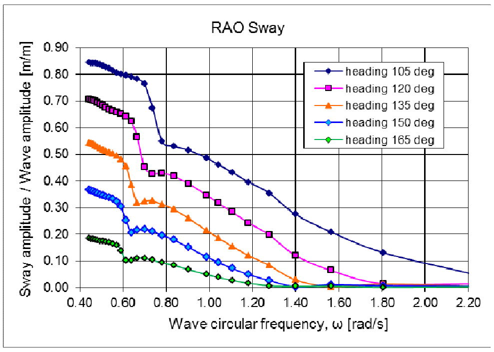

Fig. 12. RAO's sway motion (v = 12 kts)

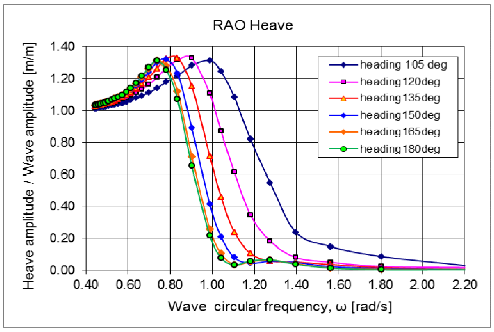

Fig. 13. RAO's heave motion (v = 12 kts)

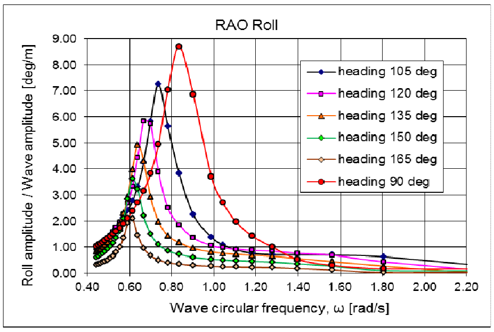

Fig. 14. RAO's roll motion (v = 12 kts)

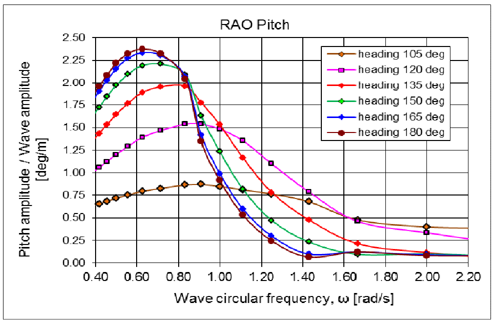

Fig. 15. RAO's pitch motion (v = 12 kts)

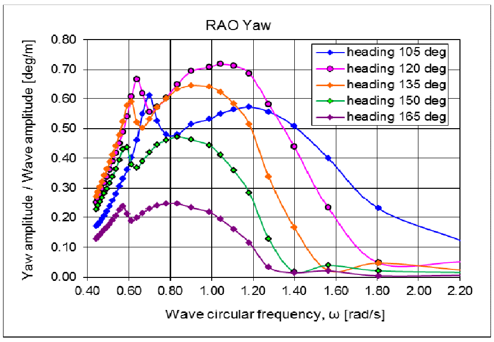

Fig. 16. RAO's yaw motion (v = 12 kts)

An evaluation of the influence of the bilge keel dimensions on roll motion, for both speeds, has been carried out in order to identify the optimum configuration [3]. In Fig. 17 is presented the influence of the bilge keel on the roll amplitude of motion for zero speed and 90° heading angle, while the same effects, corresponding to a speed of 12 kts and the same heading angle, are shown in Fig. 18. For all investigated heading angles, the results are synthetically presented in Tab. 2 and Tab. 3 respectively.

Tab. 2. Effects of bilge keel, v = 0 kts

Roll ampl. v = 0 kts	μ = 60°	μ = 75°	μ = 90°	μ = 105°	μ = 120°
without bilge keel	10.44°	10.10°	9.60°	9.69°	9.39°
bilge keel 0.26 m	**8.80°**	**8.74°**	**8.41°**	**8.41°**	**8.16°**
Attenuation [%]	15.7	13.4	12.4	13.2	13.1
bilge keel 0.32 m	**8.06°**	**7.93°**	**7.71°**	**7.62°**	**7.40°**
Attenuation [%]	22.8	26.8	20.0	21.4	21.2

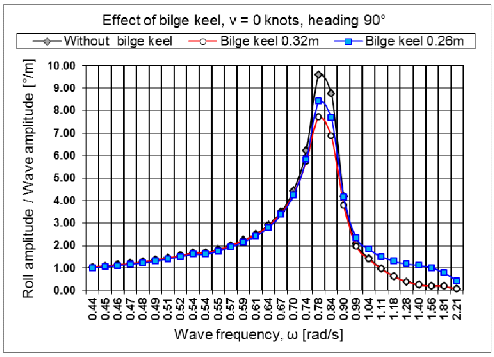

Fig. 17. Effect of bilge keel on roll motion attenuation, v = 0 kts

Tab. 3. Effects of bilge keel, v = 12 kts

Roll ampl. v = 12 kts	μ = 60°	μ = 75°	μ = 90°	μ = 105°	μ = 120°
without bilge keel	18.83°	12.26°	8.28°	6.90°	6.12°
bilge keel 0.26 m	**16.80°**	**10.48°**	**7.32°**	**6.00°**	**5.30°**
Attenuation [%]	10.80	14.50	11.60	13.00	13.40
bilge keel 0.32 m	**15.49°**	**9.57°**	**6.77°**	**5.56°**	**4.87°**
Attenuation [%]	17.70	21.90	18.20	19.40	20.40

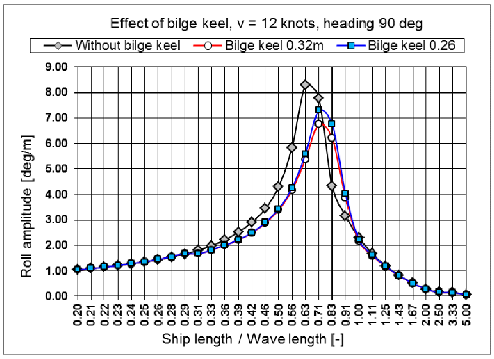

Fig. 18. Effect of bilge keel on roll motion attenuation, v = 12 kts

4. EVALUATION OF ACCELERATIONS

The results of the accelerations have been used in order to be compared with the acceptable values according to the international provisions and standards [7]. In Fig. 19 ÷ Fig. 21 the rms values [1] of the accelerations and roll motions are represented against the heading angle μ [°] and two sea states for the point P4 corresponding to the navigation deck, starboard. Comfort criteria in this location are mandatory [4] to be fulfilled.

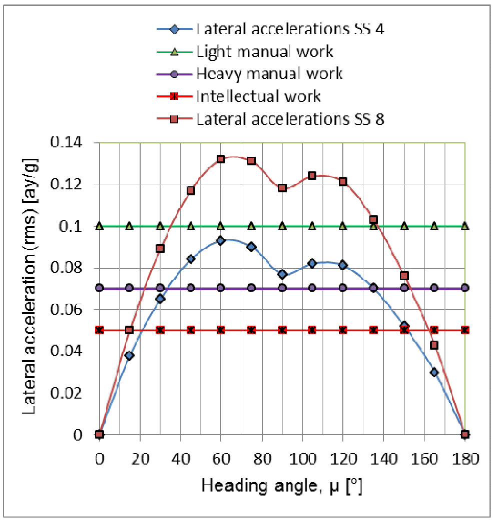

Fig. 19. Lateral accelerations for Sea States 4 and 8 compared to the acceptable limits for different activities.

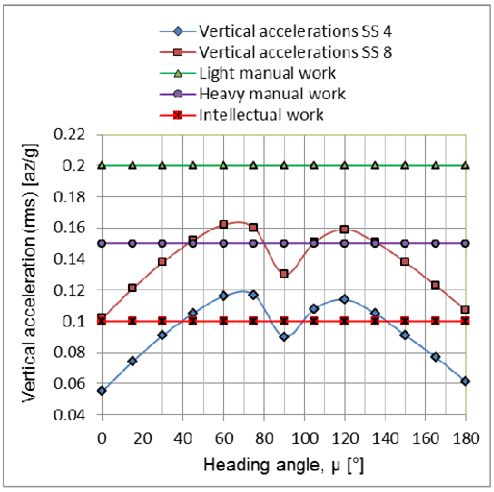

Fig. 20. Vertical accelerations for Sea States 4 and 8 compared to the acceptable limits for different activities.

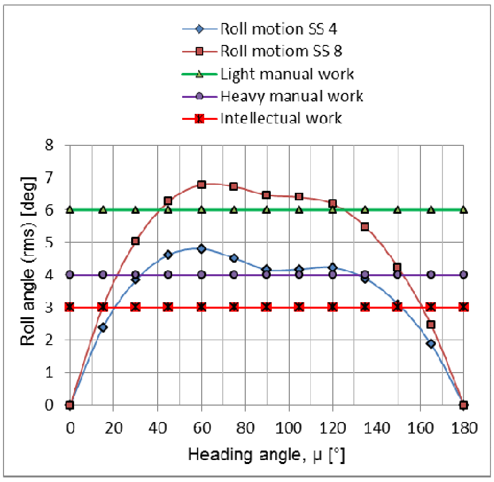

Fig. 21. Vertical accelerations for Sea States 4 and 8 compared to the acceptable limits for different activities.

The calculations have been performed for all points already mentioned.

5. CONCLUDING REMARKS

The large amount of results have been concentrated in synthetic diagrams and tables in order to be directly used for practical applications regarding the operational limitations or local scantling based on dynamic effects evaluations. As an example, for zero speed the limitations for the roll angle suggest that heavy manual work can be performed up to sea state 4 (SS 4) and up if the heading angle is not in the range of 25° - 130°. For light manual work the limit increases up to about SS 6. Lateral acceleration criterion for heavy manual work is fulfilled up to SS 8 for location P2 and up to SS 3 – SS 4 for P3 and P4 locations.

The bilge keel effect is significantly high, however, heading angles of μ = 90° have to be avoided.

Generally, the results show good seakeeping qualities and all recommendations and findings are included in the operational manual.

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