# APPLICATIONS OF PHYSICS IN MECHANICAL AND MATERIAL ENGINEERING 2021

## ” Preliminary modelling methodology of a coupled payload-vessel system for offshore lifts of light and heavyweight objects”

Anna Mackojć, Bogumił Chiliński
Institute of Machine Design Fundamentals, Warsaw University of Technology

## INTRODUCTION

The authors present the concept of a modelling methodology of a payload-vessel system allowing for a comprehensive investigation of mutual interactions of the system dynamics for lifting in air. The proposed model consists of a 6-DOF vessel and 3-DOF lifting model that can replace the simplified approach adopted for light lifts utilising RAOs and further provides the ability to analyse a wide spectrum of lifted object weights. The proposed model addresses a lack of access to reliable but simple modelling tools in terms of coupled models for offshore lifting operations.

## METHODOLOGY OF RESEARCH

Dynamics of heavy payloads cannot be considered independently to the vessel movement. DNV codes present a simplified approach for light lifts regime where the mass of the payload is not greater than 2 % of the floating unit displacement. For light lifts the crane boom can be treated as a stiff structure, hence the motion of the crane tip can be determined directly from the wave induced rigid body motion of the vessel. The wave induced translational motions (surge, sway and heave) of the crane tip are given from the vessel RAOs (response amplitude operators) for six degrees of freedom motion usually defined for the centre of gravity for the vessel. The aim of this study is to propose a coupled model which is sensitive to changes of the system parameters and allows for a comprehensive investigation of the system dynamics during the lifting in air phase.

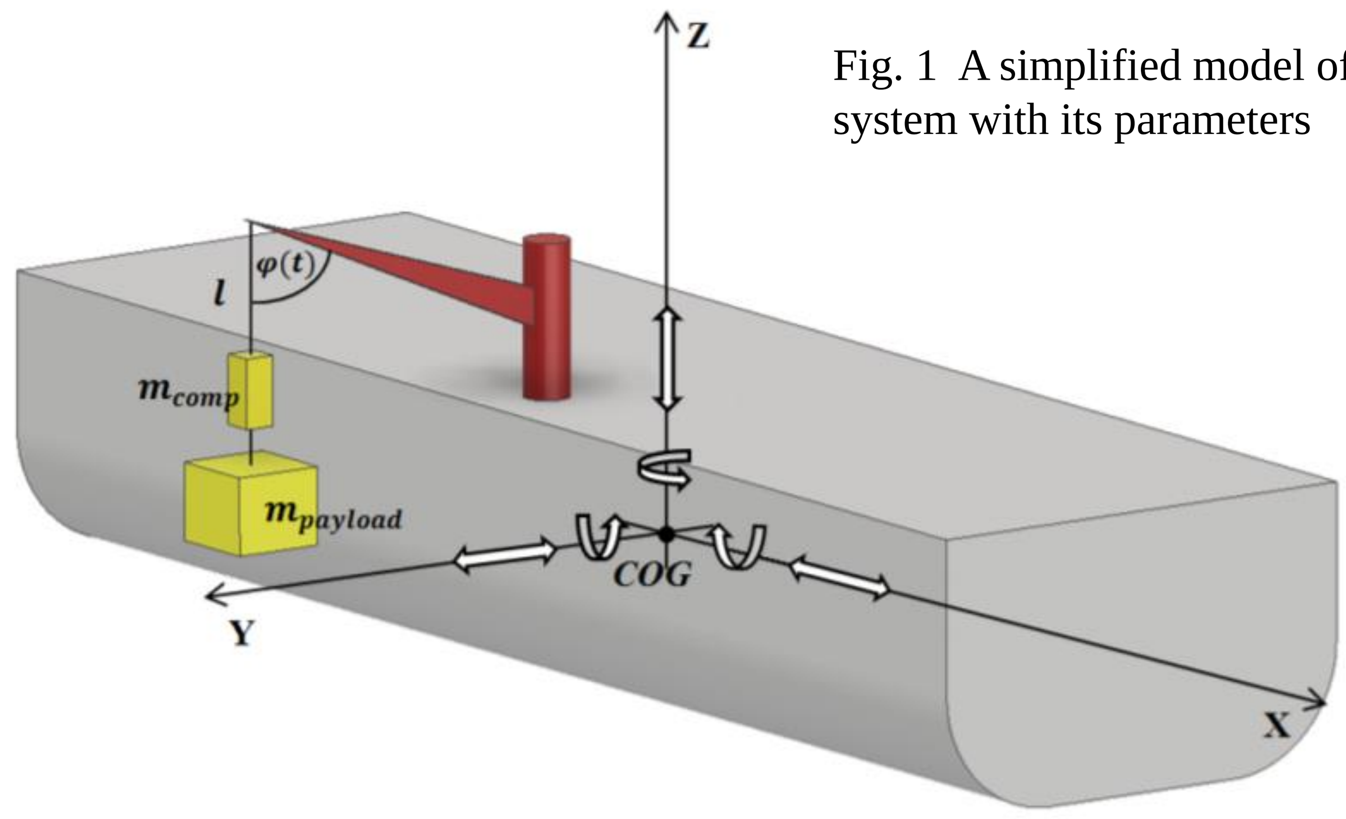


Fig. 1 A simplified model of the system with its parameters

## EQUATIONS OF MOTION OF THE SYSTEM

For this purpose, a comparative analysis was initially proposed of the payload and vessel response for a number of different payload masses. According to the authors this enables verification of the advantages of the coupled model. Moreover, the proposed approach allows the user to analyse the impact of the vessel and payload properties on the system dynamics.

$$\begin{cases} (M_V + A)\cdot \ddot{X}(\omega, \mathrm{dir}) + C_V \cdot \dot{X}(\omega, \mathrm{dir}) + K_V \cdot X(\omega, \mathrm{dir}) = F(\omega, \mathrm{dir}) \\ M_P(t)\cdot \ddot{X} + G_P(t, \dot{X})\cdot \dot{X} + C_P(t)\cdot \dot{X} + K_P(t)\cdot X = F(\dot{X}, X, t) \end{cases}$$

$M_V$ - mass matrix of the vessel,
$A$ - hydrodynamic added mass matrix,
$C_V$ - hydrodynamic damping matrix,
$K_V$ - vessel stiffness matrix,
$F(\omega, \mathrm{dir})$ - hydrodynamic force vector,
$\omega$ - natural frequency,
dir - wave direction,
$M_P$ - inertia matrix of payload,
$G_P$ - payload gyroscopic matrix,
$C_P$ - damping matrix of payload,
$K_P$ - payload stiffness matrix.

## NUMERICAL SIMULATIONS

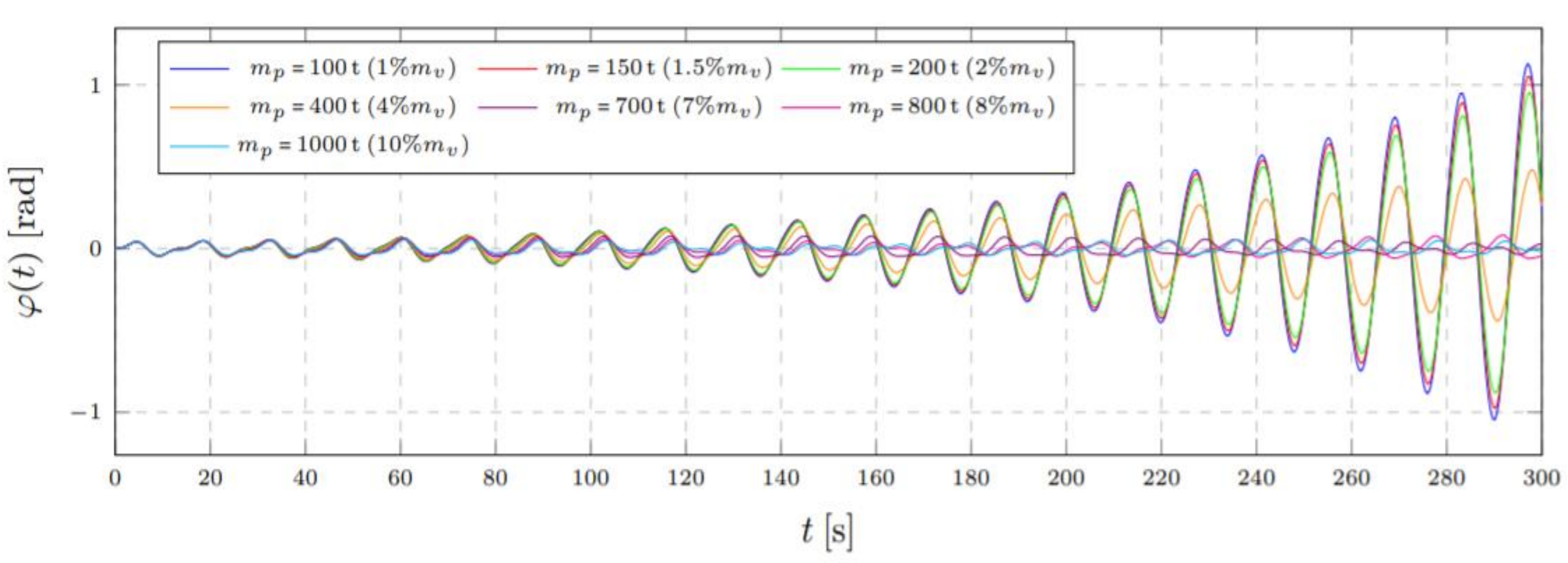


Fig. 2 Payload pendulation - comparative results for different payload weights

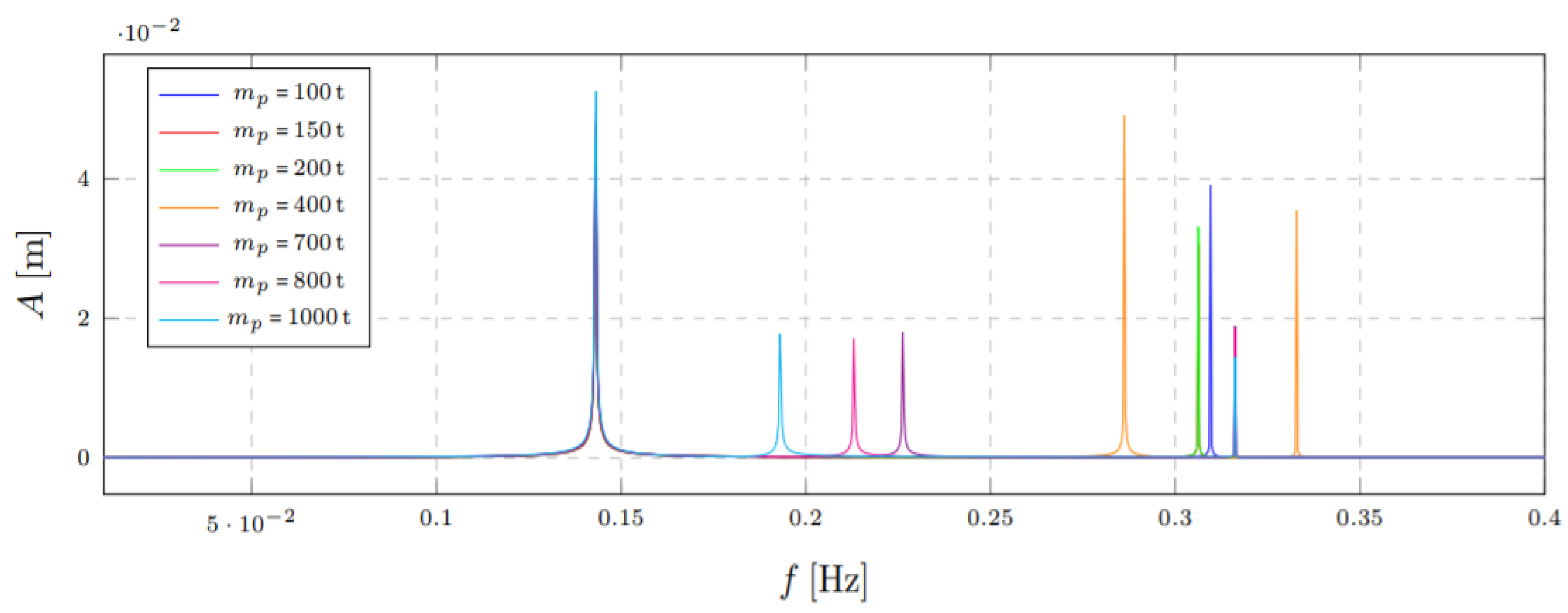


Fig. 3 Vessel heave spectrum - comparative results for different payload weights

## CONCLUSIONS

1. Payload mass to ship displacement ratios above 2 % have been investigated. The expected discrepancy in quantitative results was observed immediately past the threshold value, while qualitative divergence started to appear at around 3-4 %, which confirms the presented model gives satisfactory confirmation of the referenced assumption.
2. The research carried out for similar problems highlights the lack of availability of analytical tools for reliable payload response analysis. One might find sophisticated and complex numerical environments or overly simple dynamic models which are not able to represent the entire dynamics of payload beyond the application of the light lifts assumption. The proposed model was used to achieve the best possible efficiency for the problems within light and heavy lifts in air.
3. It can be concluded that the demonstrated approach is more widely applicable than analysis of the payload dynamics independently to a vessel. The proposed concept eliminates RAOs as a method of vessel movement representation, as this methodology is only justifiable if the light lifts assumption is fulfilled. For heavy lifts, uncoupled models cannot be utilised as high discrepancies are observed between the presented methodology and models neglecting coupling.
4. Based on the analysis carried out, it can be stated that the model proposed by the authors is more universal and comprehensive, and this is what constitutes its main advantage.