A two-step fluid-structure approach for the vibration analysis of deformable propeller blade

MARINE 2023

Quentin Rakotomalala[1,2], Lucie Rouleau[2] , Cédric Leblond[1],

Mickael Abbas[3], Jean-François Deü[2]

[1] Centre d'Expertise des Structures et Matériaux Navals
Naval Group, Technocampus Océan, 44340 Bouguenais, France
e-mail: quentin.rakotomalala@naval-group.com, cedric.leblond@naval-group.com,

[2] Laboratoire de Mécanique des Structures et des Systèmes Couplés (LMSSC)
Le Cnam, 2 rue Conté, 75003 Paris
e-mail: lucie.rouleau@lecnam.net, jean-francois.deu@lecnam.net

[3] Electrotechnique et Mécanique des Structures (ERMES) ,
Electricité de France (EDF), 7 boulevard Gaspard Monge, 91120 Palaiseau France
e-mail: mickael.abbas@edf.fr

ABSTRACT

Whether it comes from the hydrodynamic boundary layer pressure fluctuation or engine and shaft excitation, propellers blades vibrate and emit noises . A warship must keep its noise level as low as possible in order to avoid detection in combat. Civilian ships also have an interest to maintain low noise emission as it can be deterrent to the marine environment. Therefore stealth is still a major design challenge for today's ship. By transforming vibrational energy into heat, visco-elastic films can be inserted in the structure to severely reduce the radiated noise [1][2].

The computation of noise level emitted by damped propellers blades has numerous challenges as many physical phenomena are involved: the rotating blades generate lift and suffer a displacement which can be significant [3], the pressure field associated to noise is a compressible phenomenon and the damping properties of the visco-elastic material is history and pre-stress dependent.

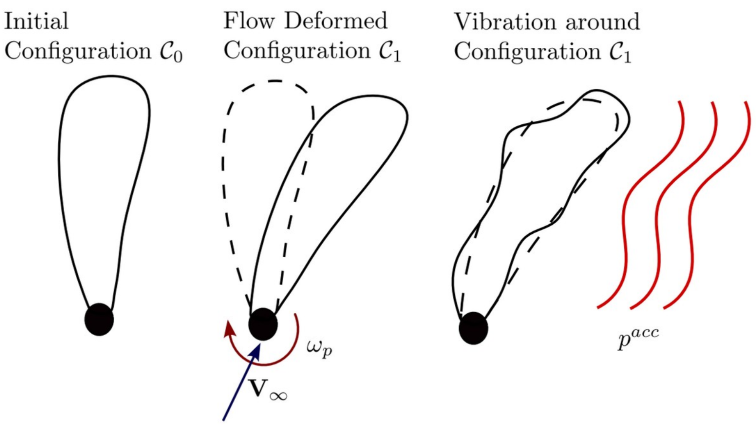

Figure 1: Phenomena separation

In this work, a simplified two step approach is proposed. The fluid is considered as non cavitating and the rotation velocity is constant and much smaller than the lowest vibration frequency studied. Two main phenomena are identified:

- The propulsion phenomenon, which takes into account the fluid structure interaction between the deformable blade and the rotating incoming static flow that leads to lift generation and structural strain.
- The vibro-acoustic phenomenon, which models the noise propagation due to vibration of the pre-stressed blade. The vibration amplitude of the structure is considered small therefore this

problem can be linearized.

This approach allows to split the non linear fully coupled dynamic problem into two chained problems: the static and non linear propulsion phenomenon imposes a pre-stress on the deformed blade which vibrates and emits noise through the vibro-acoustic phenomenon. Thefore the problem is simplified: only the computation of the pre-stressed configuration is non linear, the noise emission is computed in a linear fashion in the Fourier space at multiple frequencies. This approach was applied to the noise emission characterisation of a simplified blade geometry damped by a visco-elastic film. The blade is one meter long, with NACA 0006 sections and a chord varying linearly from 25 mm to 7,5mm immersed in water.

REFERENCES

[1] L. Rouleau, J.-F. Deü, A. Legay, and J.-F. Sigrist, ‘Vibro-acoustic study of a viscoelastic sandwich ring immersed in water’, *J. Sound Vib.*, vol. 331(3), 522–539, 2012, doi: https://doi.org/10.1016/j.jsv.2011.10.004.

[2] C. Leblond and J.-F. Sigrist, ‘A reduced basis approach for the parametric low frequency response of submerged viscoelastic structures’, *Finite Elem. Anal. Des.*, vol. 119, pp. 15–29, 2016, doi: https://doi.org/10.1016/j.finel.2016.05.002.

[3] T. Taketani, K. Kimura, S. Ando, and K. Yamamoto, ‘Study on Performance of a Ship Propeller Using a Composite Material’, *Third Int. Symp. Mar. Propulsors Launceston Tasman. Aust.*, 2013.