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Numerical investigation of the blades number effect on the bipolar noise radiation level caused by the high skew propeller

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Abstract

The main purpose of this article, is numerical modeling of the hydrodynamic noise of a high skew propeller sample from MAU marine standard series using computational fluid dynamics method with the help of Ansys-Fluent software under open water conditions. In the numerical simulation, the DES turbulence model was used, which is a good model for small vortices modeling near the wall. In order to validate the hydrodynamic and hydr-oacoustic results, the available data from the DTMB4119 benchmark propeller has been used. Comparison of the sound pressure level obtained for the DTMB4119 propeller in the present work and the available data from the reference shows a good compliance at frequencies higher than 20 Hz, but at frequencies lower than 20 Hz, about 20% error is observed. Based on the obtained results, with the increase in the number of propeller blades, the amount of vortex density around the blades decreases. The increase in the number of propeller blades has caused an increase in the average level of radiation noise in receivers at the axial direction. Increasing the number of propeller blades from 2 to a maximum of 7 blades has been able to reduce the radiated noise level in the axial direction by 15 decibels. In the radial direction, except the two-bladed propeller, the dipole radiated noises caused by the 3-7-bladed propellers have similar fluctuations. The radiated noise level value in the direction of 45 degrees, is similar for 2 until 7 blades propellers.

Keywords: Noise radiation level; CFD; DES turbulence model; DTMB4119 propeller; Number of blades.

1. Introduction

Noise is sometimes referred to as a type of annoying and unwanted sound. But from the acoustic point of view, sound and noise are a similar phenomenon, which arise from the fluctuation of pressure (increase or decrease) compared to the average atmospheric pressure around the body. Sounds are not usually emitted with a single frequency, but in general, sounds are a complex mixture of pressure fluctuations that change in phase, frequency, and amplitude. It is very difficult to obtain a mathematical relationship between different characteristics for such a complex mixture. Hydrodynamic noises are mostly caused by cavitation, bubbling currents, vortices behind the object and turbulent flow. In the absence of cavitation and bubbly flows, the noise resulting from the turbulent flow is less important than the noise resulting from the vibration of the body. Hydrodynamic noises are created for two reasons:

- The geometric shape of the moving body: in this case, due to the fluid being driven by the body, the uniform pressure of the primary fluid is disturbed and the pressure difference is created in different parts of the fluid.
- The type of flow regime around the body: Depending on the speed of the flow and the turbulence intensity, the amount of produced noise will be different. Also, this value is different according to the intensity of the vortices behind the body or the amount of flow separation on the body.

2. History of the activities

In the field of marine propeller noise, various activities have been carried out in recent years, some of which will be discussed below.
Jang et al. [1] in 2014 conducted a numerical study of propeller noise in non-cavitation flow. In this research, the pressure loading on the blades has been done using the computational fluid dynamics method and noise prediction using the LMS software and using the rotating dipole model. Based on the results of these researchers, the method used to predict propeller noise in non-cavitation flow has good accuracy. In 2015, Zeng and Du [2] studied the linear noise frequency spectrum of submerged photo-round propellers numerically. In this research, the mechanism of the interference effect as well as the effect of the harmonic field of the environment has been investigated and the

linear frequency spectrum and sound pressure direction have been analyzed. Özden et al. [3] in 2016 studied the noise of INSEAN E1619 seven-bladed propeller in different flow conditions by Fluent software. The SST k-ω model is used to simulate the flow turbulence, and a model based on the Ffowcs Williams and Hawkings equations is used for the hydro-acoustic analysis. This study showed that in the absence of a submarine body model, it is possible to predict its noise with acceptable accuracy simply by having the eddy patterns of the inlet flow to the propeller. Wei et al. [4] in 2016 investigated the reflective effect of the submarine body on the non-cavitation noise of its propeller. In this study, computational fluid dynamics method and acoustic analogy were used to predict the noise in a certain time domain. The maximum increase in sound intensity due to scattering from the surface of the body has increased with the increase in the passing frequency, so that at a frequency equal to three times the passing frequency of the propeller, the sound intensity has increased up to 20 decibels. Ghasemi et al [5] in 2018 investigated the effect of the blade tip rake angle on the hydrodynamic characteristics and noise intensity of the DTMB4382 propeller. In this study, Ansys-Fluent software was used to simulate the flow. The reason for investigating different rake angles was its effect on the creation of blade tip vortices and the propellant's emission noise level.

In this article, the numerical analysis of unsteady and rotation of propeller is done using Moving mesh method in Ansys-Fluent software. Noise is especially important in subsurface propellers, therefore, the use of MAU series high skew propeller geometry and DES turbulence model along with the effect of the number of blades on the emission noise level can be called the innovation of the present work compared to the studies done in the past.

3. Governing equations

The main equations used in this article include continuity equation, momentum equation, DES[1] turbulence model along with Lighthill's integral equations.

4. Hydro-acoustic analysis of high skew propeller

In this section, the hydro-acoustic and noise analysis of the high skew propeller will be discussed, considering the effect of the number of propeller blades from 2 to 7 blades, which is common in marine applications. Usually, in AUVs, 2 and 3 bladed propellers are used, in torpedoes, 4 and 5 bladed propellers, and in submarines, 5 and 7 bladed propellers are used. The geometric specifications of the above skew propeller are available in Table 1. It should be noted that 3, 5 and 7 bladed propellers are seen in Figure 1.

Table1. Geometric specifications of the propeller

Propeller type	High skew
Diameter [m]	0.3048
Expanded Area ratio	0.6
Pitch ratio	0.7, 0.9 and 1.1
Hub ratio	0.2
Number of blades	3,5 and 7
Rake an skew angle	Variable
Blade cross section profile	HSP-SRI-B

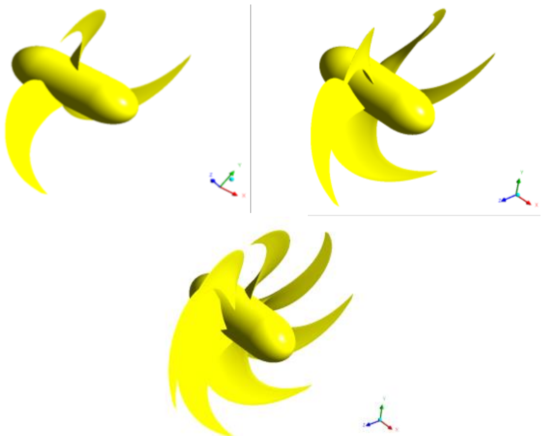


Figure 1. Geometry of high skew propellers with different number of blades

The generated network is a combination of structured and unstructured grid. In the boundary layer section, 10 layers are used with the thickness of the first layer of 0.1 mm and with a growth rate of 1.1. The solution is transient with a time step of 0.001 seconds, which is repeated 15 times in each time step. The turbulence model for simulating the flow is also the DES model. In order to check the parameters mentioned in the emission noise check, all the analyzes in this part are in the advance coefficient of 0.7 (n=843rpm, V=3m.s-1). The distance and position of the hydrophones is according to Figure 2.

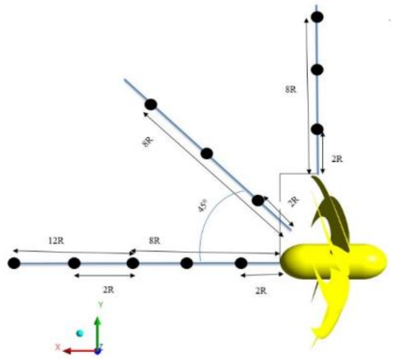
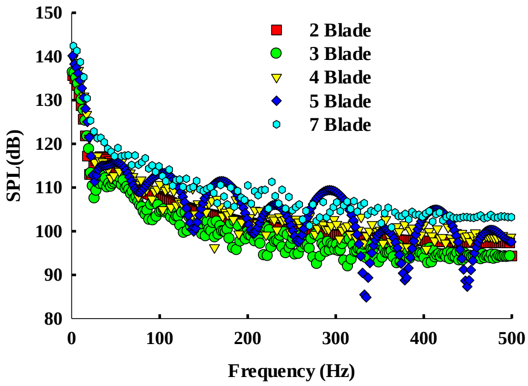


Figure 2. Position of hydrophones

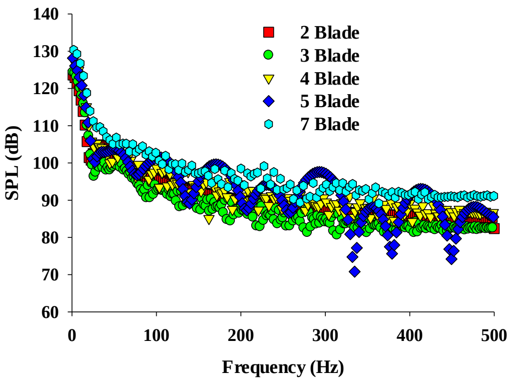
[1] Detached Eddy Simulation (DES)

5. Hydro-acoustic analysis of propeller with different number of blades

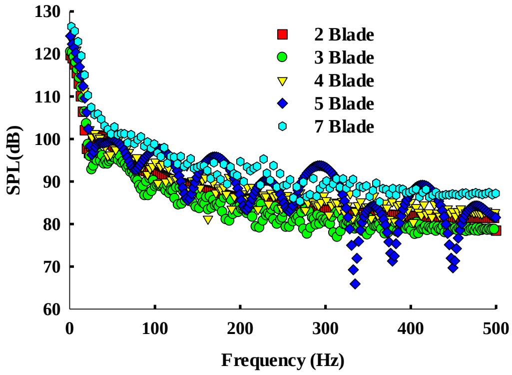
In order to investigate the effect of the number of blades on the propeller noise, high skew propellers from 2 to 7 blades have been analyzed, and the results of the investigations are as shown in Figure 3. In the direction of the axis, which is actually the direction of the fluid flow, with the increase in the number of propeller blades, the emission noise has increased. Although this increase is less than 5 decibels and in fact the emission noises caused by propellers with different blades fluctuate in a range of approximately 10 decibels, but for hydrophones and noise receivers in the axial direction, an average noise increase of up to 5 decibels is observed. Regarding the distance of the hydrophones from the source of sound emission in the axial direction, it can be said that by doubling the distance from the source of sound emission (which is the propeller), the level of emission noise has been reduced by at least 10 decibels. This amount increases with the decrease of the number of blades for propellers with different number of blades.



$\theta=0^0$ d=4R

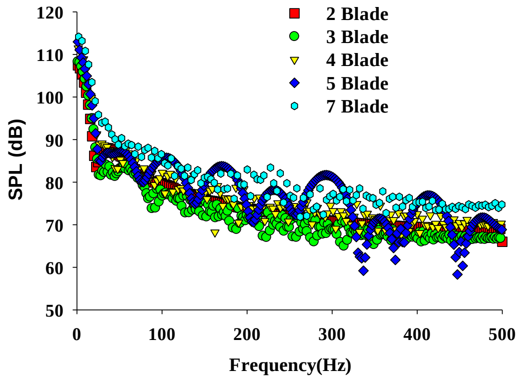


$\theta=0^0$ d=8R



$\theta=0^0$

d=10R



$\theta=0^0$ d=20R

Figure 3. Sound pressure level received from propeller with different number of blades

6. Conclusions

In this article, numerical analysis has been done using the finite volume method with the help of Ansys-Fluent software. In order to grid generated of the solution domain, the body influence grid method has been used, which has refined the size of the grid in the areas where there is the most sensitivity, and with the more precise meshing of physical phenomena such as eddies, wakes, etc., it has been better identified that, on the other hand, the size of the entire domain is reduced, and in addition to the high quality of the mesh, the cost of calculations is also reduced. The results obtained from the present research can be summarized in the following paragraphs:

1) The finite volume method is a suitable method for estimating the emission noise in marine propellers. The error rate of this method is higher at low frequencies, and with the increase of the frequency, the error rate of the diffusion noise level has decreased.

2) The level of emission noise is different based on the position of the hydrophones, which are in the direction of the flow or in the direction perpendicular to the flow, even at similar distances.

3) By increasing the number of propeller blades from 2 to 7 blades and keeping other geometrical and flow parameters constant, the emission noise level has increased.

4) By increasing the number of propeller blades, the amount of increase in the emission noise level in the direction of the flow is maximum 10 decibels.

5) By increasing the distance from the noise source, the emission noise level has decreased, and by doubling the distance, the noise reduction is about 10 decibels.

7. References

[1] J.-S. Jang, H.-T. Kim, W.-H. Joo (2014) Numerical study on non-cavitating noise of marine propeller. *INTER-NOISE and NOISE-CON Congress and Conference Proceedings*, Vol. 249, Institute of Noise Control Engineering, pp. 3017-3022.

[2] S. Zeng, X. Du (2015) Numerical simulation and analysis of non-cavitation noise line-spectrum frequency of underwater counter-rotation propeller. *International Industrial Informatics and Computer Engineering Conference*, Atlantis Press.

[3] M.C. Özden, A.Y. Gürkan, Y.A. Özden, T.G. Canyurt, E. Korkut (2016) Underwater radiated noise prediction for a submarine propeller in different flow conditions. *Ocean Engineering*, 126: 488-500.

[4] Y. Wei, Y. Shen, S. Jin, P. Hu, R. Lan, S. Zhuang, D. Liu (2016) Scattering effect of submarine hull on propeller non-cavitation noise. *Journal of Sound and Vibration*, 370: 319-335.

[5] H. Ghassemi, M. Gorji, J. Mohammadi (2018) Effect of tip rake angle on the hydrodynamic characteristics and sound pressure level around the marine propeller. *Ships and Offshore Structures*, 13: 759-768.