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Numerical analysis of enhancing water-drop fairing design to mitigate vortex-induced vibrations by applying angular slot

Content

- Introduction
- Methodology
- **Results & discussion**
- **Conclusion**

Introduction

- Marine riser
- fairing

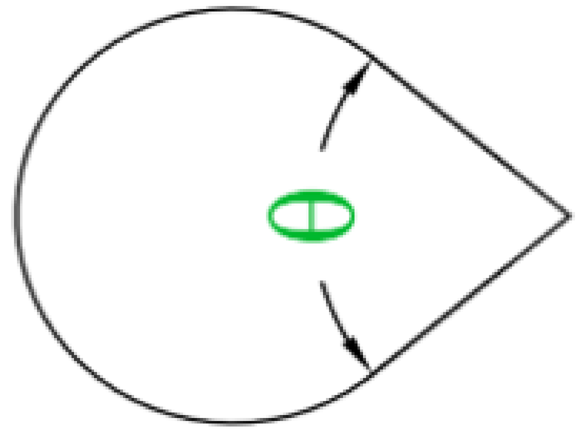
Marine risers

Marine risers are critical components of offshore oil and gas production systems that connect the bottom to the surface platform. They are subjected to vortex-induced vibrations (VIVs). As a result, marine risers are subject to collapse, which can have catastrophic consequences such as environmental damage, loss of output, and even death.

fairing

A fairing is a hydrofoil-shaped body that is applied to marine risers to reduce the influence of VIV.

The research is made on a water drop fairing with an angle $\theta = 80$.



Methodology

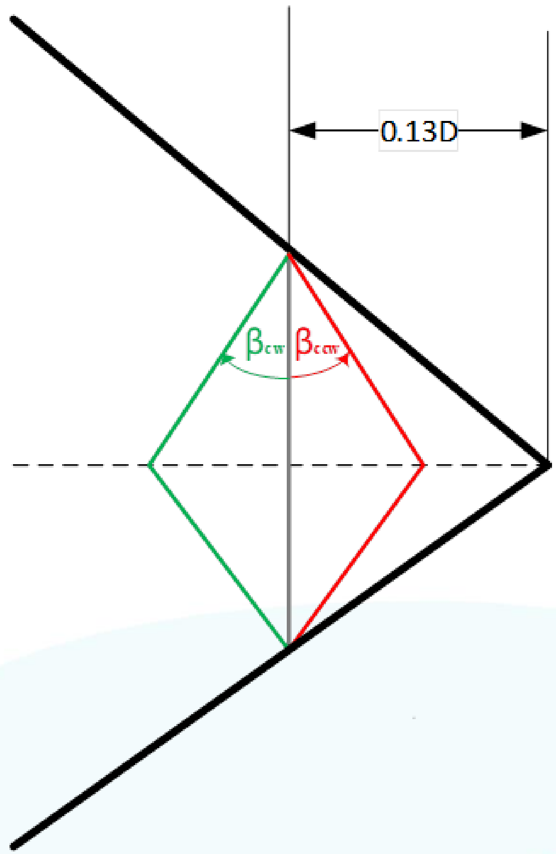
- Concept
- Software setup

concept

A vertical slot with a diameter of 0.01D was applied at the position 0.13D from the end of the fairing. The position is chosen according to previous research as it proves to be the ideal position to apply a vertical slot on this fairing.

The angle β is either measured clockwise βcw or counterclockwise βccw. the angle is increased from 0 to 40 in both directions with a step size of 5.

The behaviour of the fairing in VIV is compared using the root mean square of the lift coefficient (Cl_{RMS}). The angle between the slot and the vertical is altered to discover the ideal angle that shows the lowest value of Cl_{RMS}.



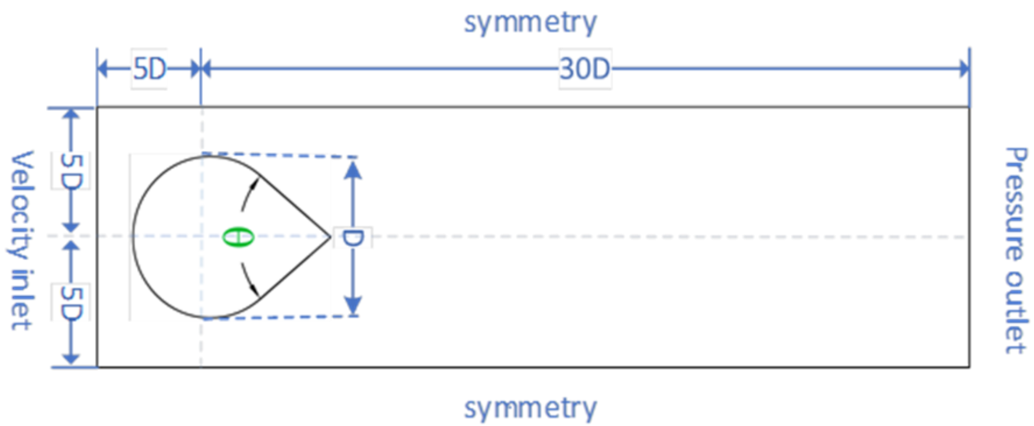
Software setup

Domain	
Upstream	5D
Downstream	30D
inlet & outflow width	10D

D = 1 meter

v = 1m/s ⟹ $Re = 10^6$

Boundary condition	
inlet	Velocity inlet
Outlet	Pressure outlet
Wall	Symmetry
Fairing	Non-slip

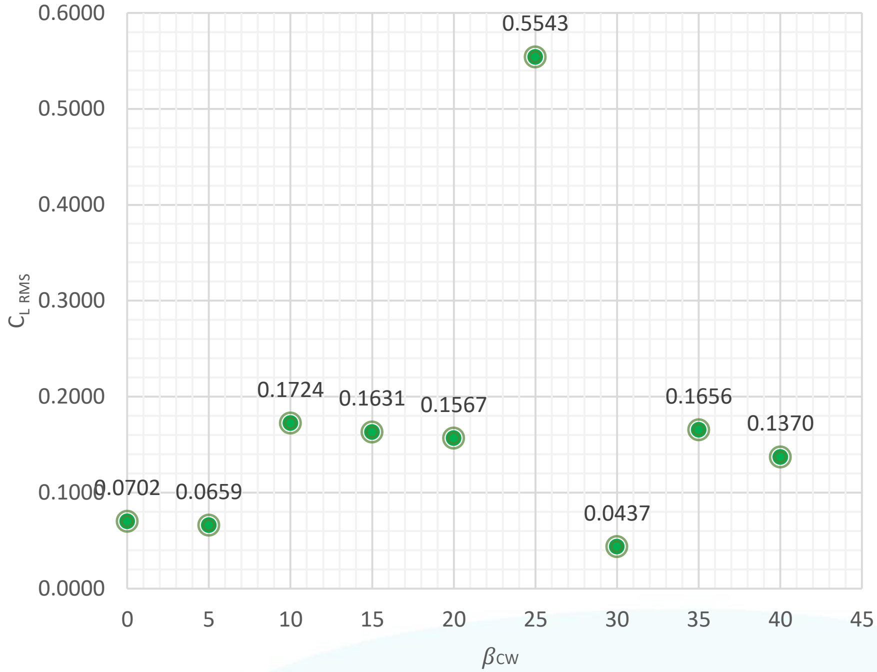


The simulation model was run on a PC with a CPU Intel® Core™ i7-12700 and 32 GB ram using ANSYS fluent software. In order to obtain the densest possible mesh, a total of 873154 elements are utilized, with each element having a minimum size of 0.02 mm, which is the smallest size that the PC is capable of handling.

Results & discussion

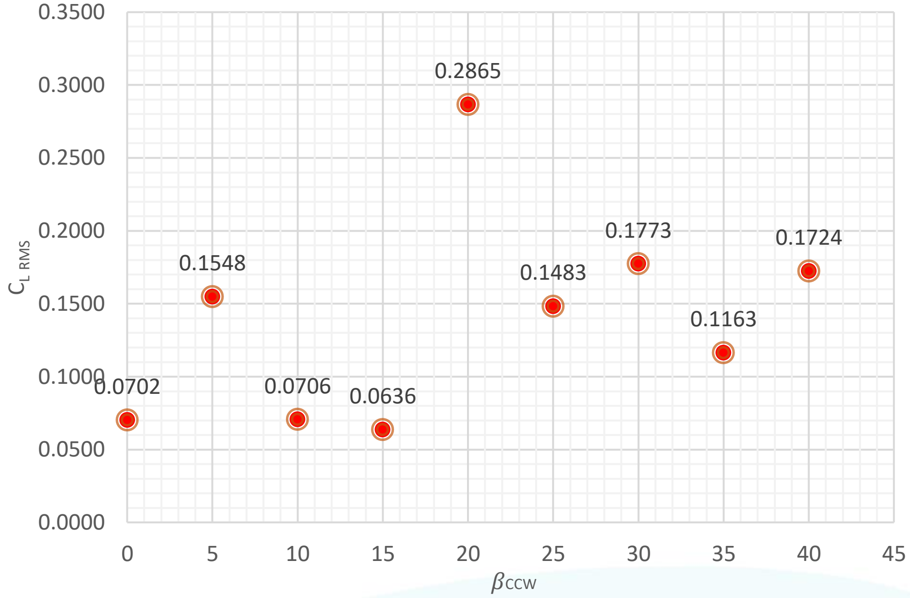
C_d , C_l, and $C_{l\ RMS}$ for a water-drop fairing with clockwise angled slot

β_{cw}	C_d	% increase or decrease	$C_{l\ RMS}$	% increase or decrease
0	**0.1624**	**Datum**	**0.0702**	**datum**
5	0.1203	-25.94	0.0659	-6.11
10	0.1193	-26.52	0.1724	145.50
15	0.1223	-24.72	0.1631	132.27
20	0.1149	-29.21	0.1567	123.19
25	0.1296	-20.18	0.5543	689.41
30	0.1203	-25.95	0.0437	-37.83
35	0.1160	-28.58	0.1656	135.84
40	0.1233	-24.06	0.1370	95.19

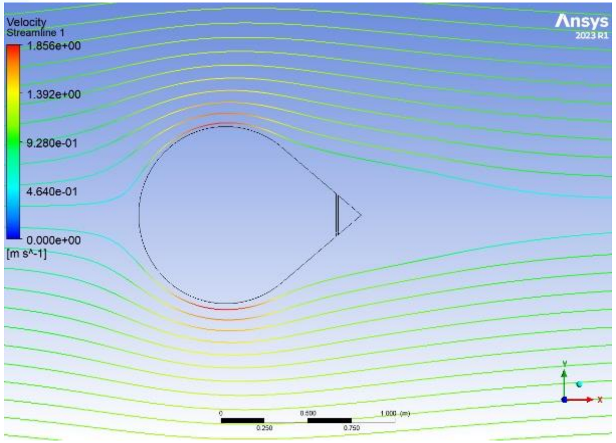


C_d , C_l, and $C_{l\ RMS}$ for a water-drop fairing with counterclockwise angled slot

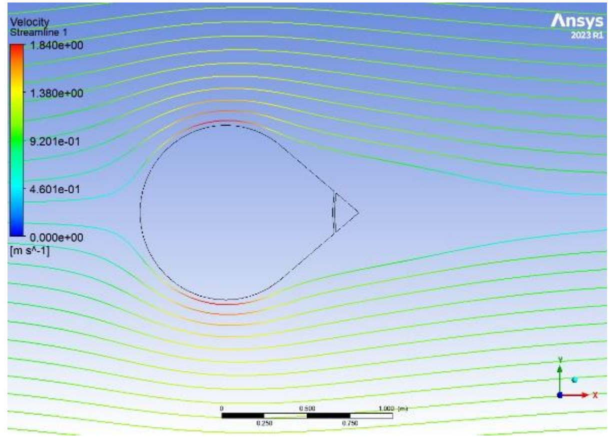
β_{ccw}	C_d	% increase or decrease	$C_{l\ RMS}$	%increase or decrease
0	**0.1624**	**datum**	**0.0702**	**datum**
5	0.1625	0.06	0.1548	120.49
10	0.1615	-0.56	0.0706	0.62
15	0.1620	-0.23	0.0636	-9.38
20	0.1755	8.08	0.2865	308.06
25	0.1066	-34.36	0.1483	111.24
30	0.1599	-1.53	0.1773	152.54
35	0.1584	-2.44	0.1163	65.68
40	0.1880	15.76	0.1724	145.50



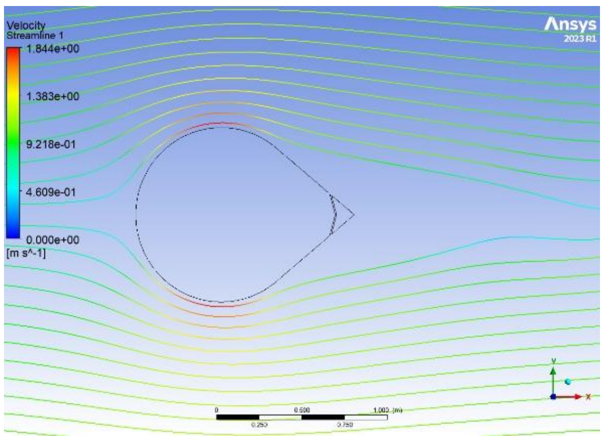
velocity streamline for different angled slot fairing



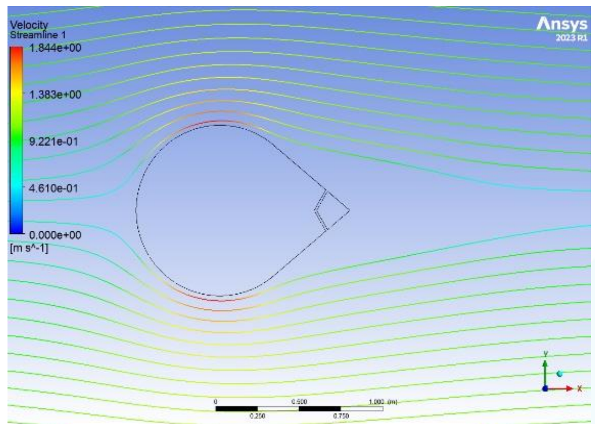
vertical slot



$\beta = 5° \; cw$



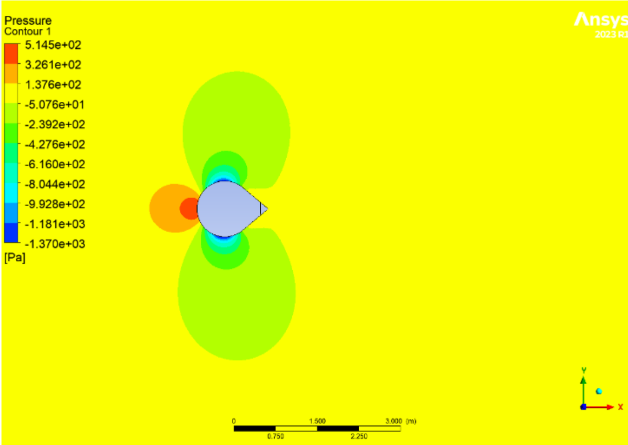
$\beta = 15° \; ccw$



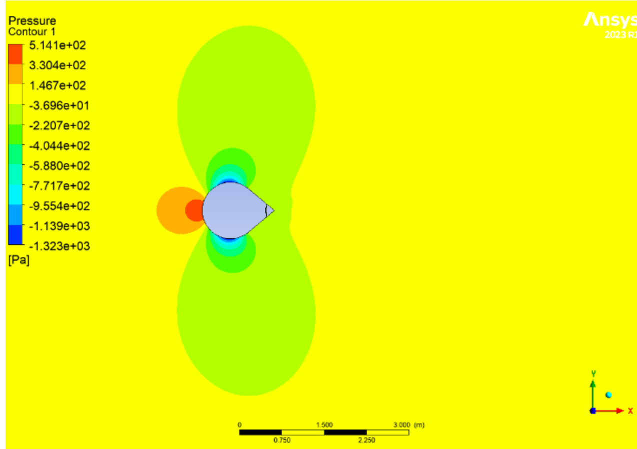
$\beta = 30° \; cw$

The velocity streamline visualization reveals that the flow boundary layer detaches later for angled slot fairings in comparison to the vertical slot. The delayed separation observed suggests enhanced flow adherence and decreased pressure fluctuations, resulting in reduced VIV amplitudes.

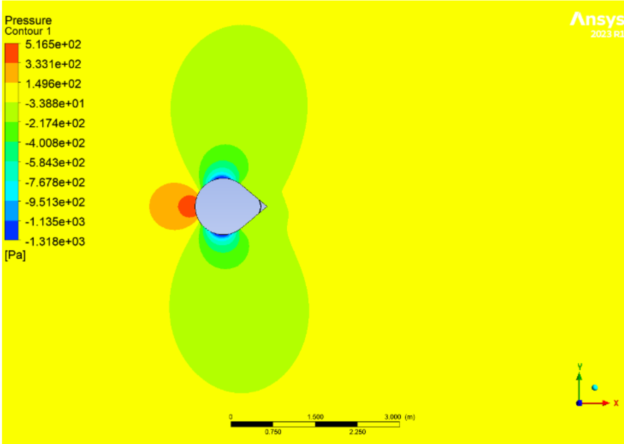
pressure contours for different angled slot fairing



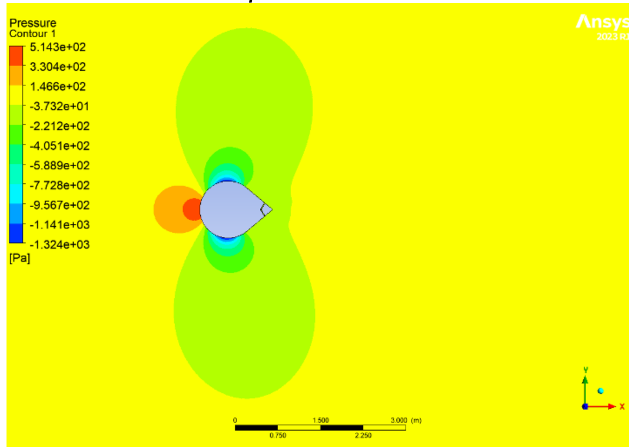
vertical slot



$\beta = 5° \ cw$



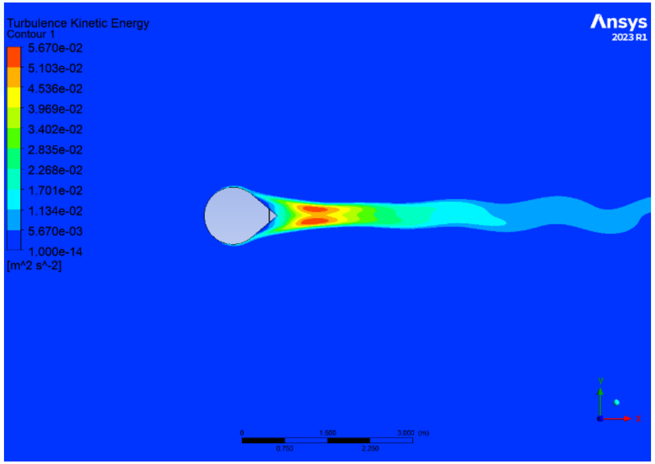
$\beta = 15° \ ccw$



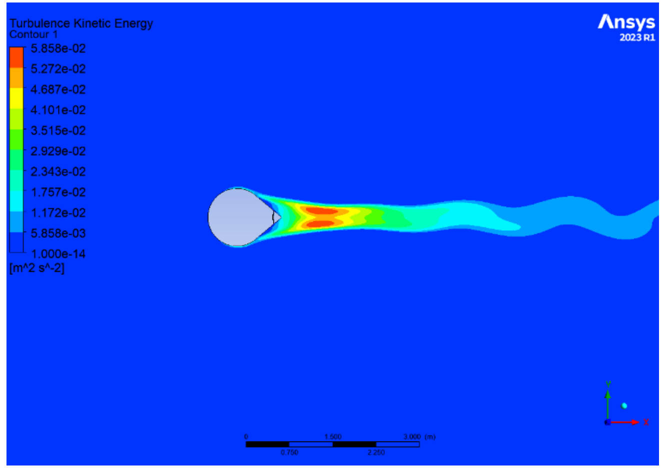
$\beta = 30° \ cw$

The comparison of pressure contours clearly demonstrates a noticeable change in the wake area when using angled slot fairings as opposed to vertical slot. The observed change suggests a disturbance in the regular patterns of vortex shedding, which result in a decrease in VIV as anticipated by the flow models.

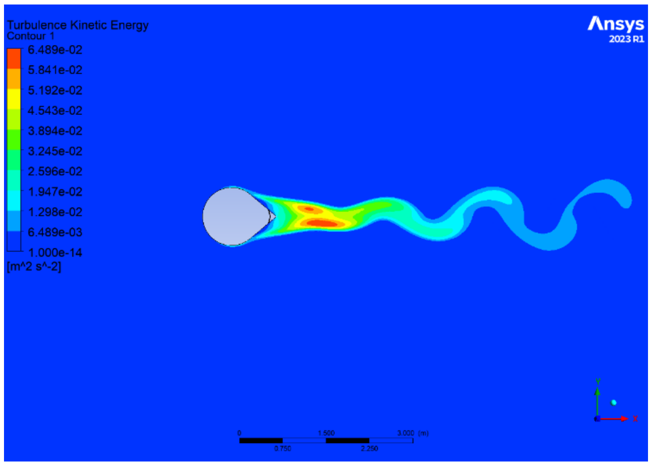
Turbulent kinetic Energy contours for different angled slot fairing



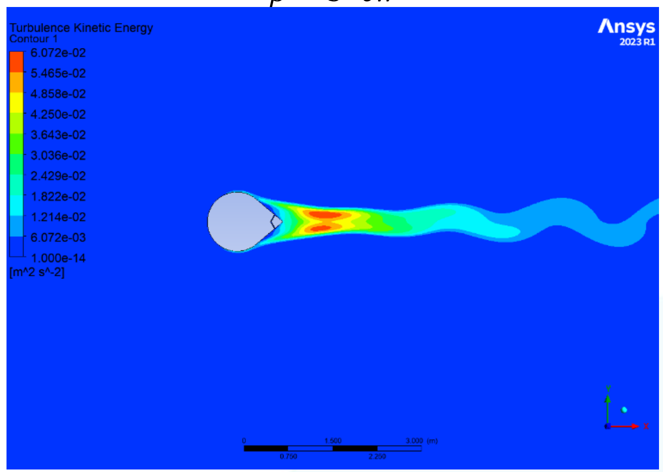
Vertical slot



$\beta = 5^\circ cw$



$\beta = 15^\circ\ ccw$



$\beta = 30^\circ cw$

The figure shows that angled slot fairings demonstrate a noticeably lower overall level of Turbulence kinetic energy compared to the vertical slot, signifying a decrease in the overall energy associated with turbulent fluctuations. This suggests a calmer flow regime and potentially reduced energy transfer to the cylinder, leading to lower VIV response.

Conclusion

The fairing with an angle β equals 30 cw with vertical has proved to be the best in damping VIV as its results show the lowest value of Cl RMS. it shows a decrease of 37.8%. additionally, the slots with an angle β = 15 ccw and 5 cw is good as they shows a drop in Cl RMS by 9.38 % and 6.11 % respectively compared to the vertical slot.

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