A study on the energy transfer of a square prism under fluid-elastic galloping

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Abstract

Extracting useful energy from flow induced vibrations has become a developing area of research in recent years. In this paper, we analyse power transfer of an elastically mounted body under the influence of fluid-elastic galloping. The system and the power transfer is analysed by numerically integrating the quasi-steady state model equations. The power transfer is analysed for both high ($Re = 22300$) and low ($Re = 200$) Reynolds numbers cases.

A combined mass-damping coefficient, Π_2, that can be derived from the equation of motion, is shown to be the parameter that governs power output. The system is a balance between the power delivered to the system due to fluid-dynamic forcing and power removed through mechanical damping which are governed by the fluid-dynamic forcing characteristics (i.e. the lift force as a function of incident angle) and mechanical damping coefficient respectively. Comparing the DNS results with the QSS data uncovered that a good agreement of the data could be obtained even at low Reynolds numbers when the inertia of the system (mass ratio) is substantially high.

Keywords:

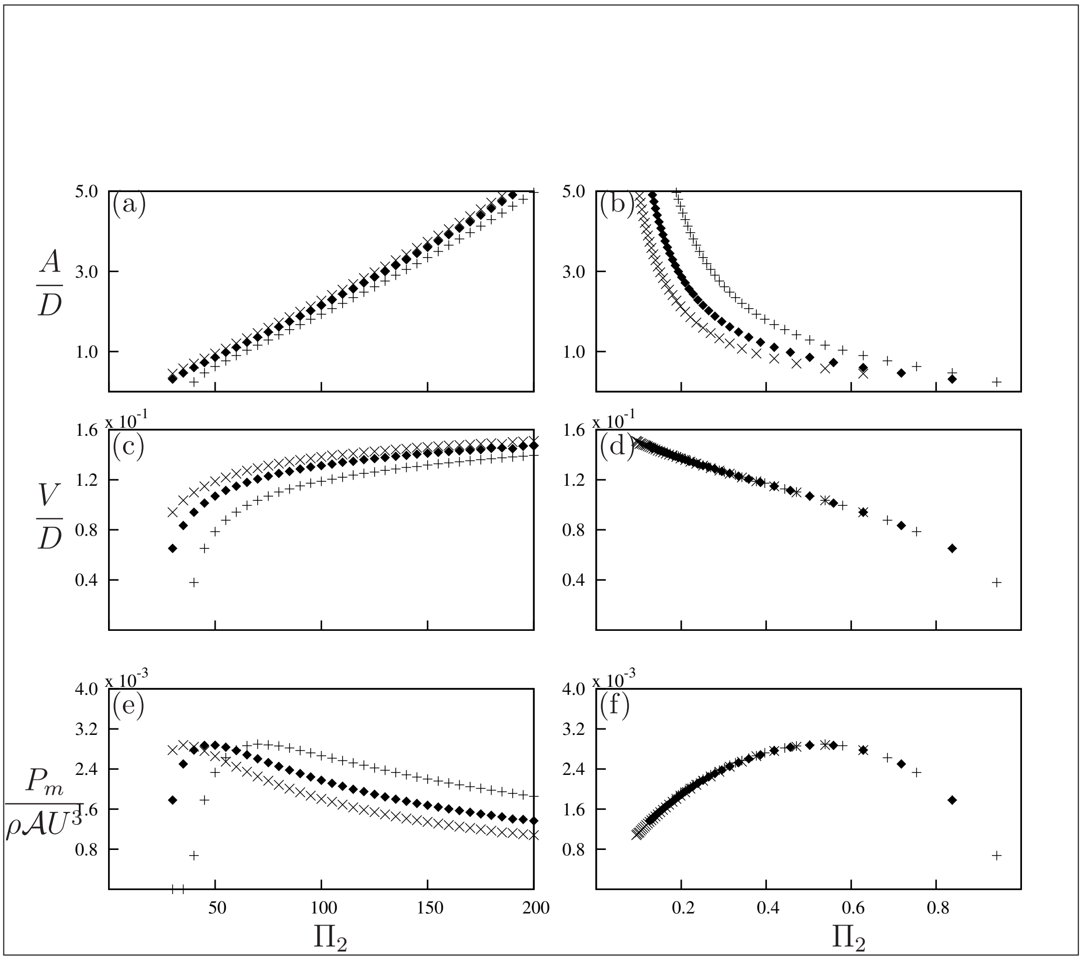


Figure 1: Comparison of the mean power data using different independent variables. (a) using classical VIV parameters U^* and ζ at $Re = 200$ and $m^* = 20$ at three different damping ratios: $\zeta = 0.075$ ($\times$), $\zeta = 0.1$ ($\blacklozenge$) and $\zeta = 0.15$ ($+$) and (b)the same data collapsed using Π_2 as the independent variable.

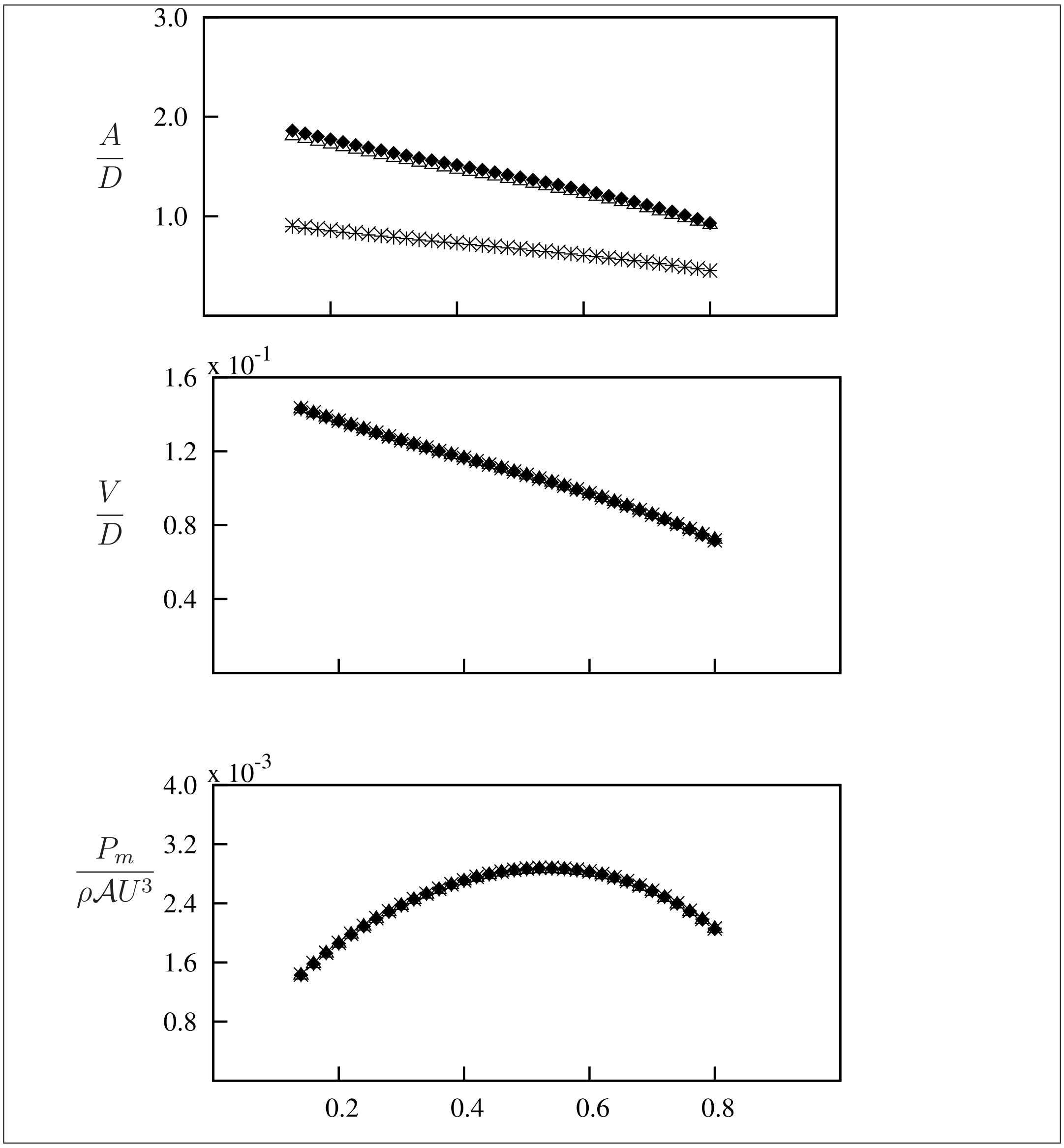


Figure 2: QSS data at high Π_1 levels. (a) displacement amplitude, (b) velocity amplitude and (c) mean power as a function of Π_2. Data presented at four different combined mass-stiffness levels. $\Pi_1 = 10$ ($m^* = 20,\ U^* \approx 40$) (◆), $\Pi_1 = 100$ ($m^* = 130,\ U^* \approx 80$) (+) and $\Pi_1 = 1000$ ($m^* = 400,\ U^* \approx 40$) (△)

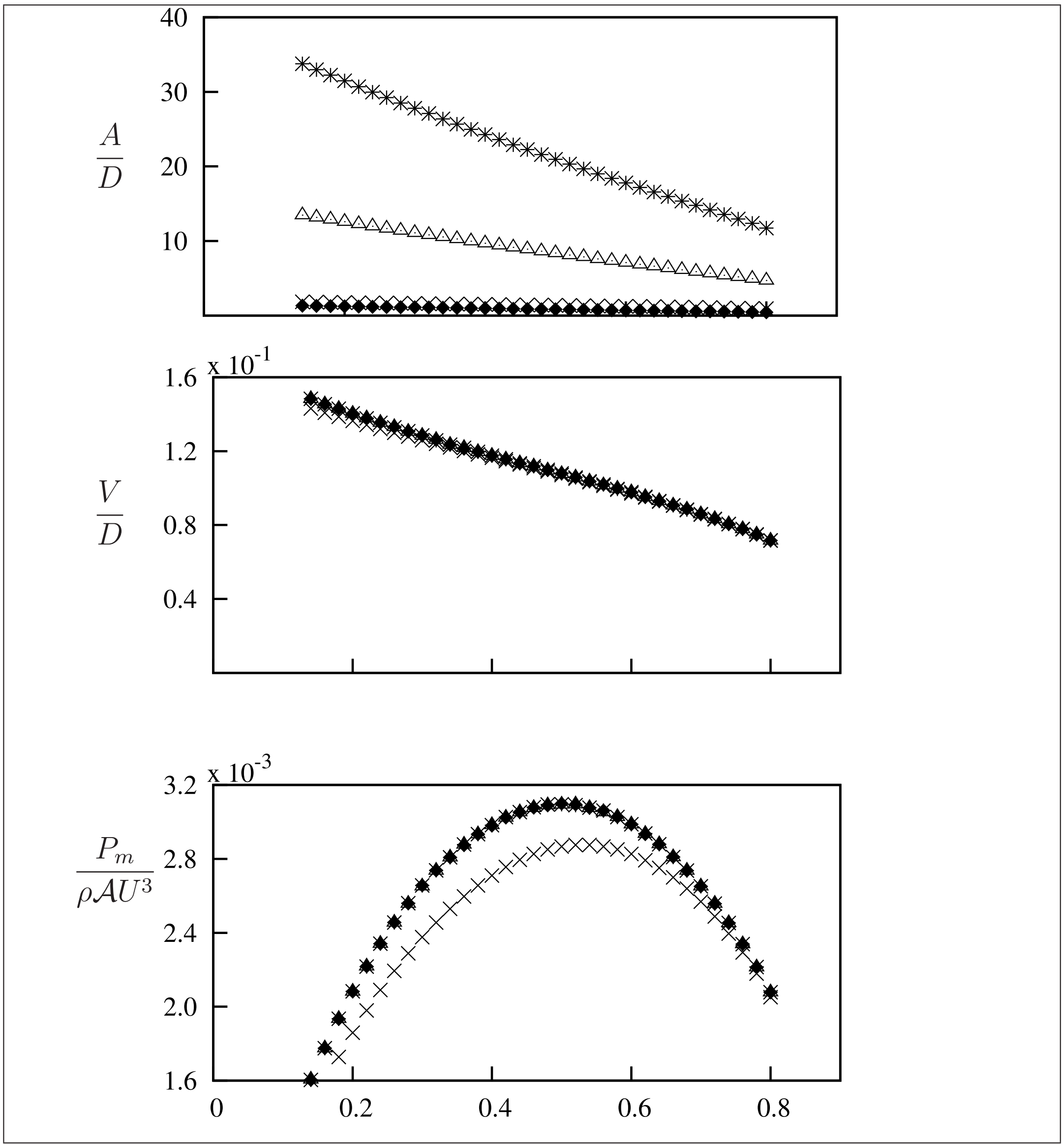
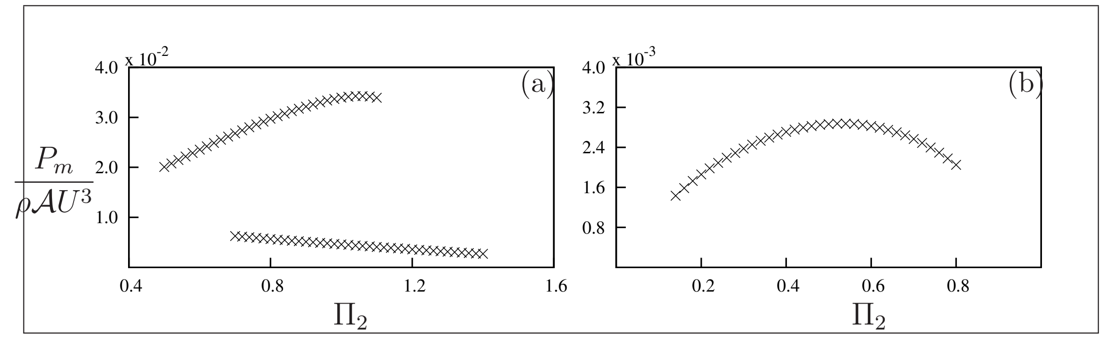


Figure 3: Comparison of QSS data at high and low Π_1. (a) displacement amplitude, (b) velocity amplitude and (c) mean power as a function of Π_2. Data presented at $\Pi_1 = 100\, m^* = 130(+)$, $\Pi_1 = 0.1\, m^* = 2$ (◆), $\Pi_1 = 0.1\, m^* = 20$ (△) and $\Pi_1 = 0.1\, m^* = 50$ ($*$)



4.0 x 10^-2
3.0
2.0
1.0
(a)
0.4
0.8
1.2
1.6
Π_2
$\frac{P_m}{\rho \mathcal{A} U^3}$
4.0 x 10^-3
3.2
2.4
1.6
0.8
(b)
0.2
0.4
0.6
0.8
Π_2

Figure 4:

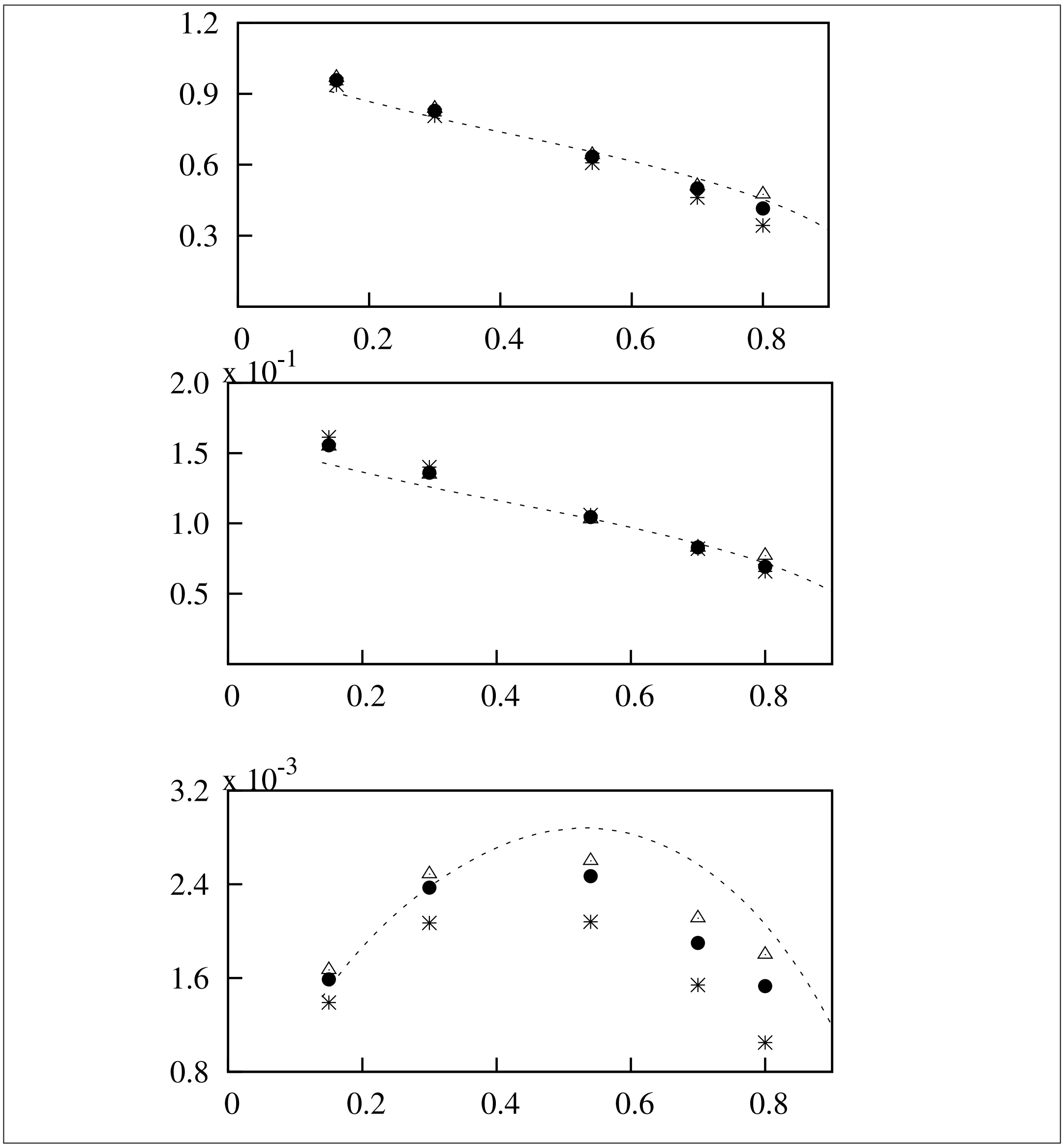


Figure 5: Comparison of data generated using the quasi-static theory and full DNS simulations . (a) Displacement amplitude, (b) velocity amplitude and (c) mean power as functions of Π_2. Data were obtained at Re = 200 at three different combined values $\Pi_2 = 10$ ($m^* \approx 20$) ($\circledast$), $\Pi_2 = 60$ ($m^* \approx 50$) ($\bullet$), $\Pi_2 = 250$ ($m^* \approx 100$) ($\triangle$), $\Pi_2 = 1000$ ($m^* \approx 250$) and $\Pi_2 = 6200$ ($m^* \approx 500$)

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