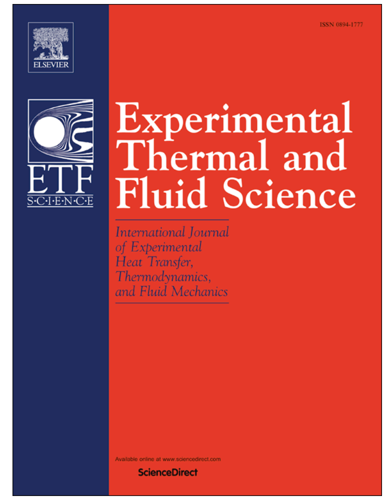

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Flow-Induced Motions of Flexible Filaments Hanging in Cross-Flow

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Abstract

Experiments were carried out to study the dynamics of hanging cantilever flexible filaments in air cross-flow. Thirteen flexible filaments of 0.61 mm diameter and lengths from 20 mm to 60 mm were tested with wind speeds in the range of 1 m/s to 15 m/s, corresponding to Reynolds numbers of $25<Re_d<610$ and reduced velocities in the range of $5<U^*<130$. Two synchronized fast-imaging cameras were used to reconstruct the motion of the filaments in three dimensions, and a blend of linear and on-linear time-series analysis techniques was used to analyze the observed dynamics. Long filaments show a rich dynamics as the wind speed is gradually increased, ranging from small amplitude vibration to large amplitude limit-cycle oscillation and to a more complex chaotic motion. However, short filaments only exhibit a small amplitude vibration-like motion throughout the range of wind speeds tested. Turbulent buffeting is identified as the main source of excitation responsible for the observed filaments dynamics. The results highlight the importance of the filament damping ratio, which is modulated by the filament length, as a controlling parameter for the dynamics of flexible filaments in cross flow, in addition to the flow velocity. The Scruton number for these tests correspond to $31<Sc<86$.

Key words: flexible fluid-structure interaction; filament; turbulence-induced vibration; turbulence buffeting; limit-cycle oscillation

1. Introduction

Fluid-structure interaction problems with flexible structures are becoming increasingly important in engineering applications. Examples include flexible marine propellers (Young, 2008), flexible turbomachinery for biomedical applications (Campbell and Paterson, 2011), flapping wing propulsion for micro aerial vehicles (Unger et al., 2012), flexible bladed wind turbines (MacPhee and Beyene, 2016), towing cables (Obligado and Bourgoin, 2013; Wang et al., 2008),