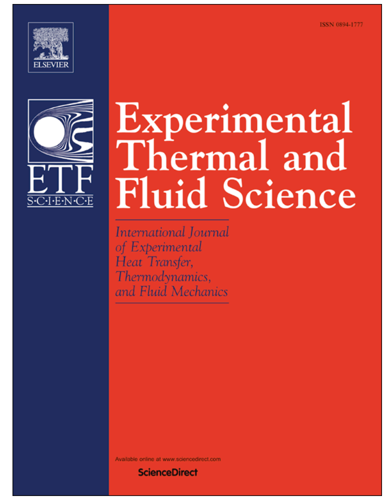
Accepted Manuscript



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PII: S0894-1777(18)30317-0
DOI: https://doi.org/10.1016/j.expthermflusci.2018.02.036
Reference: ETF 9397

To appear in: *Experimental Thermal and Fluid Science*

Received Date: 28 August 2017
Revised Date: 31 January 2018
Accepted Date: 28 February 2018

Characteristics of the wall shear stress in pulsating wall-bounded turbulent flows

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Abstract

A pulsating turbulent pipe flow has been investigated experimentally using hot-film anemometry and particle image velocimetry. Particularly, a 'paradoxical phenomenon' that is known to occur for a range of forcing frequencies and time-averaged Reynolds numbers has been investigated in detail. The paradoxical phenomenon is that the oscillating component of the wall shear stress exhibits a smaller amplitude in a turbulent flow compared to in a laminar flow exposed to the same oscillation in the pressure gradient. In here, the phenomenon is explained by splitting the response of the wall shear stress into one contribution resulting from the imposed pressure gradient $\widetilde{\tau}_p$, and a second contribution resulting from the oscillating Reynolds shear stress, $\widetilde{\tau}_t$. At the conditions of maximum reduction of the wall shear stress amplitude, $\widetilde{\tau}_p$ and $\widetilde{\tau}_t$ are nearly 136 degrees out of phase. The contributions are thus interfering destructively, this being the ultimate reason for the reduced amplitude. It is also shown that the level of reduction is dependent on the imposed forcing amplitude, this in turn residing from a dependence of the time-development of the oscillating Reynolds shear stress on the forcing amplitude.

Keywords:

1. Introduction

Turbulent flows perturbed by sinusoidal unsteadiness are ubiquitous in engineering applications such as the flows in hydropower turbines, turbomachines and combustion engines. The present work investigates a non-zero mean turbulent pipe flow subjected to sinusoidal unsteadiness; i.e., a pulsating flow.

Due to the imposed oscillations, the 'traditional' Reynolds decomposition is not suitable for studying pulsating flows. Instead, a triple decomposition as

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