Experimental investigation of a Single Droplet Interaction with Shear Driven Film

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Abstract

The main objective of this work is to visualize and clarify the outcomes of a water droplet interaction with shear-driven films in rectangular duct. Droplet diameters used in this study ranging from 2.2 to 4.8 mm. The shearing air velocity is between 4.5 and 15 m/s. The film thickness is 0.3 to 2 mm. Two high speed cameras are used to track the droplet and visualize the film surface. A laser focus displacement meter (LFDM) is used to obtain the instantaneous and average film height. By analyzing the acquired images along with the film height different regimes for both droplet deformations in air and impact outcomes are observed. A regime map is produced relating the air, film and droplet properties with the outcomes of the interaction between the droplet and the moving water film.

Introduction

The impact of liquid droplets onto moving liquid films is of great interest in many industrial applications, for example cooling flows within the power generation industry, in cylinder flows within car engines and lubrications flows with aeroengines. Previous research has focused on the impact of droplets onto static films, for example [1]. Although published research [2, 3] has investigated droplets in shear-driven liquids, there was no published work that shows detailed aspects of the dynamics of the impact of single droplet with shear-driven film.

This paper is one of a series of papers by the authors investigating the impact of droplets onto moving liquid films [4].The case considered in this paper is the impact of a single water droplet upon a shear-driven water film in rectangular duct. A single droplet is ejected vertically through the air to impact upon a wavy film. For more illustration of the case, figure 1 shows a sketch of the problem.

The main aim of this study is to visualize and clarify the impact phenomena and its outcomes. A regime map is also produced to show the effect of air and film movement on different impact outcomes.

Materials and Methods

The shear- driven rig used in this experiment is illustrated in details in ref [5]. The main part of the rig is the transparent rectangular duct (25x161x2000 mm) through which the air (4.5 – 15 m/s) is blown over a thin water film (0.3 – 2 mm). A droplet is generated by using a syringe pump which ejects a droplet through a vertical tube mounted on the duct (figure 1). Droplets diameters used in this experiment are ranging from 2.2 to 4.8 mm. The droplets and the film are both produced from tap water.

Two high-speed cameras were synchronized to track the droplet movement from side and above of the duct (snapshot of a sequence of the impact is shown in figure 2). Acquired images are then processed by using MATLAB software and quantitative results for the original and secondary droplets are then obtained. The instantaneous and average film thickness is obtained with high accuracy by using laser focus displacement meter (LFDM) film thickness measurement device.

All devices used in this experiment were calibrated to ensure that the provided results are accurate. The uncertainties are also calculated and found to be reasonable for the experiment.

Results and Discussion

After calibrating all the measurement devices and processing the acquired images the results of this experiment are categorized mainly in three sections. First an extensive investigation was done to identify quantitatively the film thickness and the film wave patterns (see figure 3) for the range of the experiment. Then droplet deformation through the shearing air and before the impact is also studied and compared with regimes published in the literature [6]. Finally a regime map for the droplet impact outcomes is produced.

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Acknowledgement

The corresponding author acknowledges Libyan cultural affairs for sponsoring his PhD research. Special thanks to the ESPRC who provided the Photron high speed imaging system.

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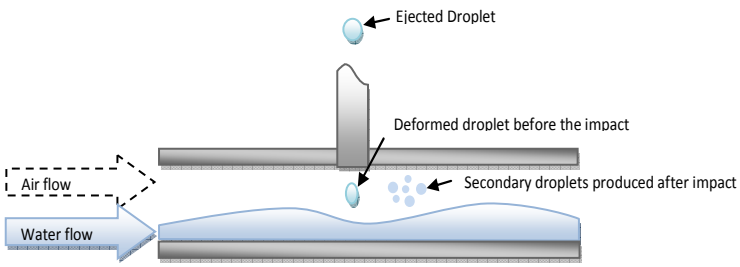
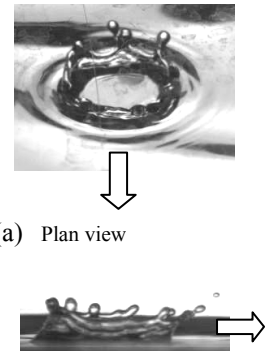


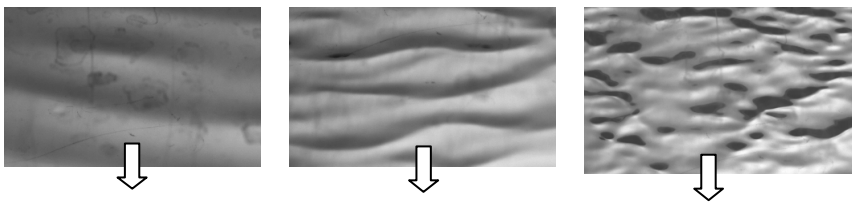
Figure 1. Schematic of the problem at the test section



(a) Plan view

(b) Side view

Figure 2. A snapshot from a sequence of the impact of 3.8mm water droplets on film (a) shown in figure 3a (the arrows indicates the direction of film movement)



a. 2D waves b. 3D Waves **c.** Roll Waves

Figure 3. Plan view of images of the surface waves for different air/water setting.