

FREE-SURFACE SYNTHETIC SCHLIEREN IMPLEMENTATION ON A WAVE FLUME

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INTRODUCTION

Many applications of fluid mechanics involve the presence of interfaces between different fluids. In particular, the dynamics of the water-air free surface is of interest. The most used instruments to measure the height of a wave are the capacitive and resistive gauges. This type of instrument measures the water free surface elevation at a given location and is easy to implement in flumes or tanks. These probes provide measurements at a single point and must be used in line or array configuration to access spatial information. However, this type of instrument is intrusive and can significantly affect the surface, precluding the measurement of smaller scales, such as reflection of waves.

Since the 90's, optical techniques have been developed that use one or several cameras to study changes in the free surface, reconstructing the topology of the surface. According to Meerkerk et al., (2020) and Gomit et al., (2022) optical techniques can be divided into 3 categories based on: the projection of patterns or stripes, the stereoscopic correlation of images and the optical properties of light when traveling at the interface between two fluids, this is, the refraction, reflection and absorption.

Free Surface Synthetic Schlieren (FS-SS) is within the latter, developed by Moisy et al., (2009) and draws attention as no sophisticated equipment is required to reconstruct the free surface. The technique consists of photographing an aleatory dot pattern on the flume bottom with the still water and then recording the dot pattern with the fluid in motion. The relative motion or virtual displacement (δr) field of the dots due to the perturbation on the free surface (refraction of the light) is measured using cross correlation similar to Particle Image Velocimetry (PIV) technique. Finally, the height of the topography of the surface is obtained from an inverse gradient computation of the displacement field usually solved using the Newton-Raphson method.

This technique has been implemented in multiple fields of study such as the research carried out by Damiano et al., (2016). They analysed the topography generated by the rebound of drops on water surface measuring perturbations of the order of 10^{-2} mm. Li et al., (2021) developed a processing method like FS-SS but without the need for a reference height. They demonstrated that the height of the free surface of a dynamic phenomenon can be studied and applied to a dam break on a laboratory scale. However, although the order of their measurements does not exceed 7 mm in height.

To the authors' knowledge, Oldenzel et al., (2023) were the first to apply the technique in offshore engineering applications. They studied the interaction between an incident regular wave field and a monopile. The study area

was relatively large (0.5×0.5 m²). FS-SS technique can measure waves with heights up to 0.3 m. The traditional setup for this technique can be seen in Fig. 1; it is easy to implement and consists of a random pattern of dots placed in the background (bottom of the tank or flume), a camera, a light source, and a computer to perform image post-processing and analysis.

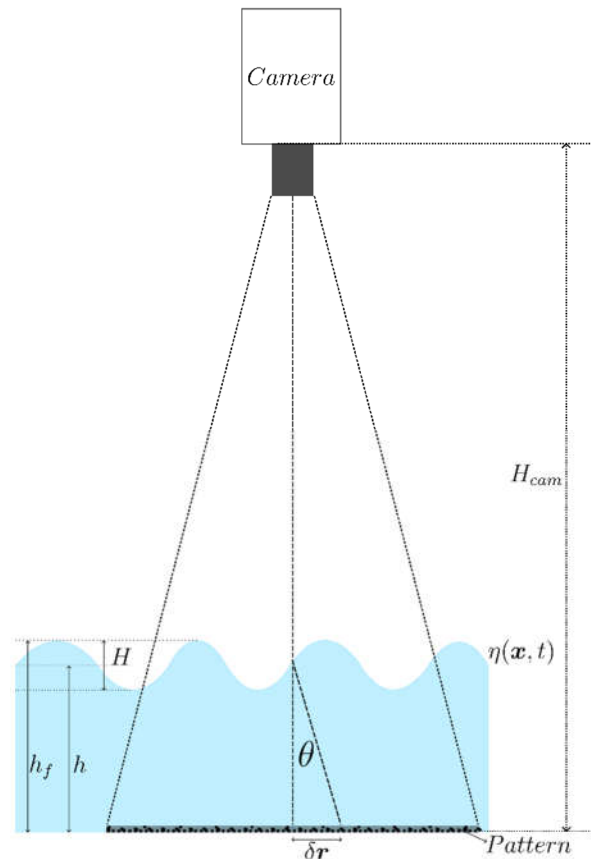


Figure 1 - Sketch of experimental setup for FS-SS. Where η is the wave-profile (relative to still water level), wave height H , still water level h , camera height H_{cam} , free-surface level h_f , apparent displacement δr and angle of refraction θ .

Among the advantages of FS-SS:

It can be achieved with inexpensive equipment (mainly video camera and illumination requirements).

If a high-speed camera is used, time resolution will improve.

Spatial resolution is proportional to the camera sensor resolution (number and pixel size), as well as the size of the dots and pattern density.

While wave gauges can easily measure the water level locally, FS-SS allows to measure the topography of the

region of interest.

The limitations of this technique are: It is sensitive to slight vibrations. It is unable to determine the displacement field for strong curvature and/or large surface-pattern distance. It applies only for weak deformations, weak slopes and weak paraxial angle.

The objective of this work is to implement the FS-SS in a wave flume of 22 m long and 0.4 m wide which features a piston type wavemaker with a dynamic absorption system attached, as well as to analyse the limits of the technique due to the configuration of facility. Another objective is to study the wave dynamics between a double submerged breakwater. Usually, experiments carried out with these breakwater configurations use capacitive or resistive probes, located down and up stream of the breakwaters (Cao et al., 2012), while the region comprised between them remains unstudied.

EXPERIMENTAL SETUP

The experimental work was conducted in the wave-wind flume of the Institute of Engineering of the National University of Mexico. The experimental set up is shown in Fig 2.

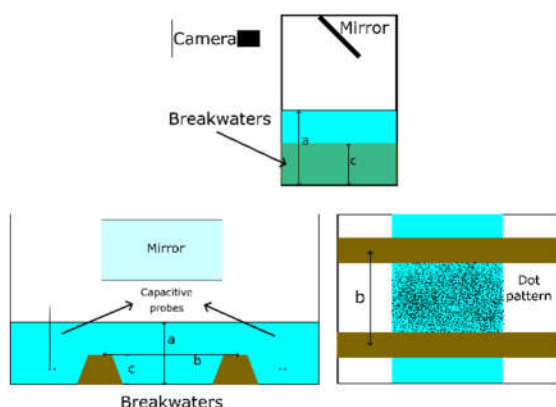


Figure 2. Experimental setup. a) Cross section, b) Plan view, c) Side view. Where a is the still water level, b is the breakwaters separation and c is the breakwaters height.

The experimental programme included regular and soliton waves with heights of 5 to 10 cm. The still water level was set to 0.3 m. The separation of the breakwaters is from 0.25 to 1 wave length. Wave gauges were placed before and after the breakwater as reference. The submerged double breakwater trapezoidal with a height of 15 cm.

This is a work in progress, the limits of the FS-SS technique will be discussed in the final version, as well as the instantaneous free-surface elevations between the double submerged breakwater and the validation with the capacitive level sensors.

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