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PIV Study of the Interrogation Area Size Effect on the Hydrodynamic Results of a Stirred Vessel Equipped by an Eight Flat Blades Turbine

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Abstract: The aim of this paper is to investigate the interrogation area size effect on the hydrodynamic results of a stirred vessel equipped with an eight flat blades turbine. Particle image velocimitry (PIV) technique was used in order to compute the velocity field in the vessel. This PIV system is equipped with a Nd:YAG 532 nm laser, a CCD camera and a mini synchronizer. In this study, it has been observed that the interrogation area size has a direct effect on the results efficiency. According to the achieved results, for a grid size between 12x12 pixel² and 128x128 pixel², it has been observed that the parameters selection has a great influence on the experimental results. Particularly, it has been noted that the maximum areas size increases by increasing the interrogation area size.

Keywords: PIV, Stirred Vessel, Flat Blade Turbine, Interrogation Area Size

1. Introduction

PIV technique has frequently used to calculate the velocity field in various sectors and particularly for the stirred vessel. Obviously, it is known that all numerical and experimental results are heavily built on several parameters. Particle size as well as light wavelength, laser pulses, camera resolution and interrogation area size are often studied to enhance results efficiency. In order to overlap the ambiguity caused by these parameters, Crouss and Epstein [1] evaluated the PIV technique for transonic and supersonic flow with a particle seeding in the 0.2 to 0.5 micron range. Boillot et al. [2] presented a process to estimate the time separated two successive laser pulses. Ben amira et al. [3] studied the hydrodynamic structure of the flow in a stirred vessel generated by the up-pitched blade turbines with different blade inclinations. Nasibov et al. [4] utilized enhancement approach using ROI option of imaging camera sensors to improve the performance of digital particle image velocimetry (DPIV) systems. Moreover, Gilo and Kääb [5] evaluated the performance of two different approaches to achieve sub-pixel precision of normalized cross-correlation. Pfadler et al. [6] validated the sub grid scale (SGS) models for large-eddy simulations (LES) of turbulent premixed flames experimental validation by PIV experience. Hinsch et al. [7] discussed the autocorrelation function for a large area interrogation in a PIV technique. Shah et al. [8] studied two different interrogation areas and overlaps effect on the PIV images process. Shi et al. [9] proposed multi-grid and iterative image deformation cross-correlations to improve two widely used particle-image velocimetry (PIV) algorithms with time-resolved PIV data-processing. Weng et al. [10] linked the central difference particle image pattern matching and image distortion analysis to resolve flow fields from coarsest grid to super-resolution grid. Datta et al. [11] used the pixel by pixel correlation method for consecutive frames in a given sensor plane to estimate particulate velocity components. Then, Nguyen et al. [12] investigated the accuracy of the stereo particle image velocimetry in the boundary position. Cameron [13] studied the accuracy, the resolution and the limitation of PIV algorithm in an open channel flow.

According to these researches, it is clear that the PIV parameters have an effect on the results. For this reason, we are interested on the study of the interrogation area size effect on the accuracy of the results for a range of 12x12 pixels² to 128x128 pixels² of area size.

2. Material and Method

Figure 1. *Experimental apparatus.*

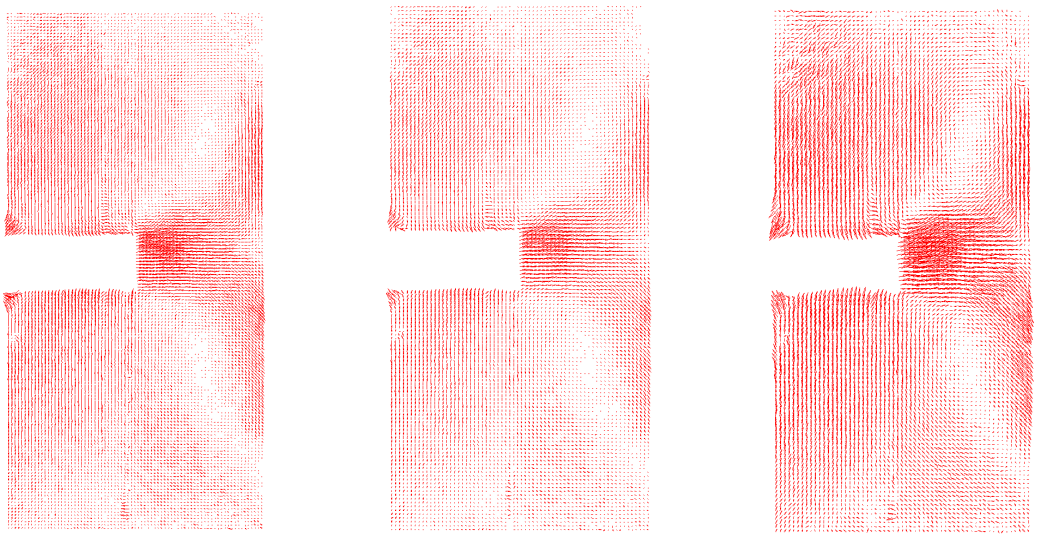
Figure 1 shows the cylindrical tank used in our experience which is equipped with a height flat blades turbine. The water height is settled to be equal to the cylindrical tank diameter (H=D=300 mm). The vessel is mounted with particle image velocimetry (PIV) equipped with double pulses Nd:YAG laser working in 2x30 mJ and 532 nm wavelength. The laser sheet propagated along the centerline of the tank and vertically along the shaft. Furthermore, the acquisition is achieved with a CCD camera with 1600 x 1200 pixels as resolution. A mini-synchronizer system is used to provide the synchronization between the different PIV compartments to have results in the plane midway between two blades. The images are analysed by commercial software 'Vid PIV'. The interrogation windows area is settled to be in a range of 12x12 pixels² to 128x128 pixels². Moreover, the successive recorded images were superposed by an overlap equal to 50%.

3. Experiment Results

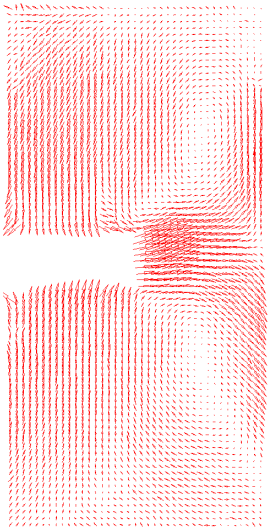
In this study, the Reynolds number is taken equal to Re=26250. The seeding particles concentration is equal to 0.15 g in the whole volume of the tank. Furthermore, 170 paired images are taken in the treatment.

3.1. Velocity Fields

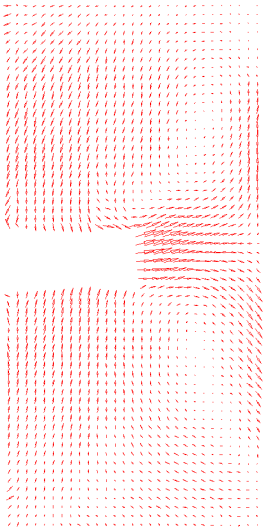
Figure 2 shows the velocity fields for different interrogation areas sizes. According to these results, it is seen that the size of the velocity increases by increasing of the interrogation area size and the recirculation loops becomes larger. Moreover, it has been observed that the number of the validated vectors increases with the interrogation areas size. In fact, for an interrogation area size more than 32x32 pixel² the validated vectors becomes equal to 100% which means that the normalized autocorrelation function has no erroneous vectors. Furthermore, the interrogation area size equal to 32x32 pixel² has the most important value of the validated vectors for the rest of areas sizes. For the mean velocity, the largest value is presented for interrogation area size equal to 32x32 pixels² (table 1).



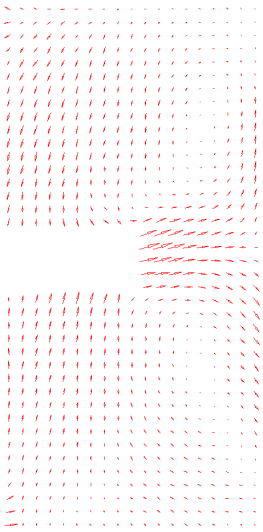
(a) 12x12 pixels² (b) 14x14 pixels² (c) 16x16 pixels²



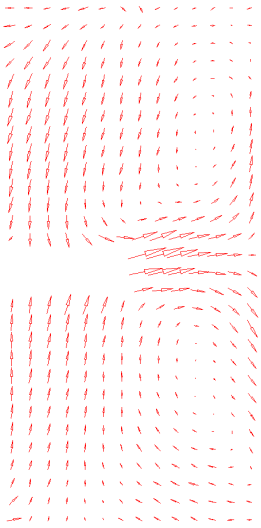
(d) 24x24 pixels²



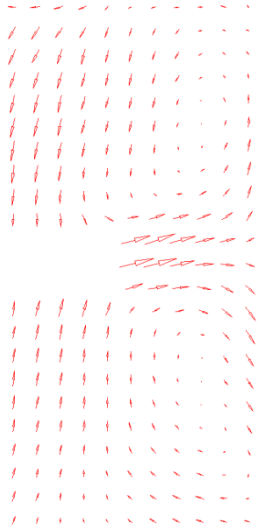
(e) 32x32 pixels²



(f) 48x48 pixels²

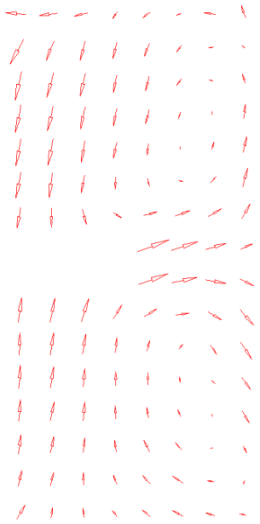


(g) 64x64 pixels²



(h) 80x80 pixels²

(i) 96x96 pixels²



(j) 112x112 pixels²

(k) 128x128 pixels²

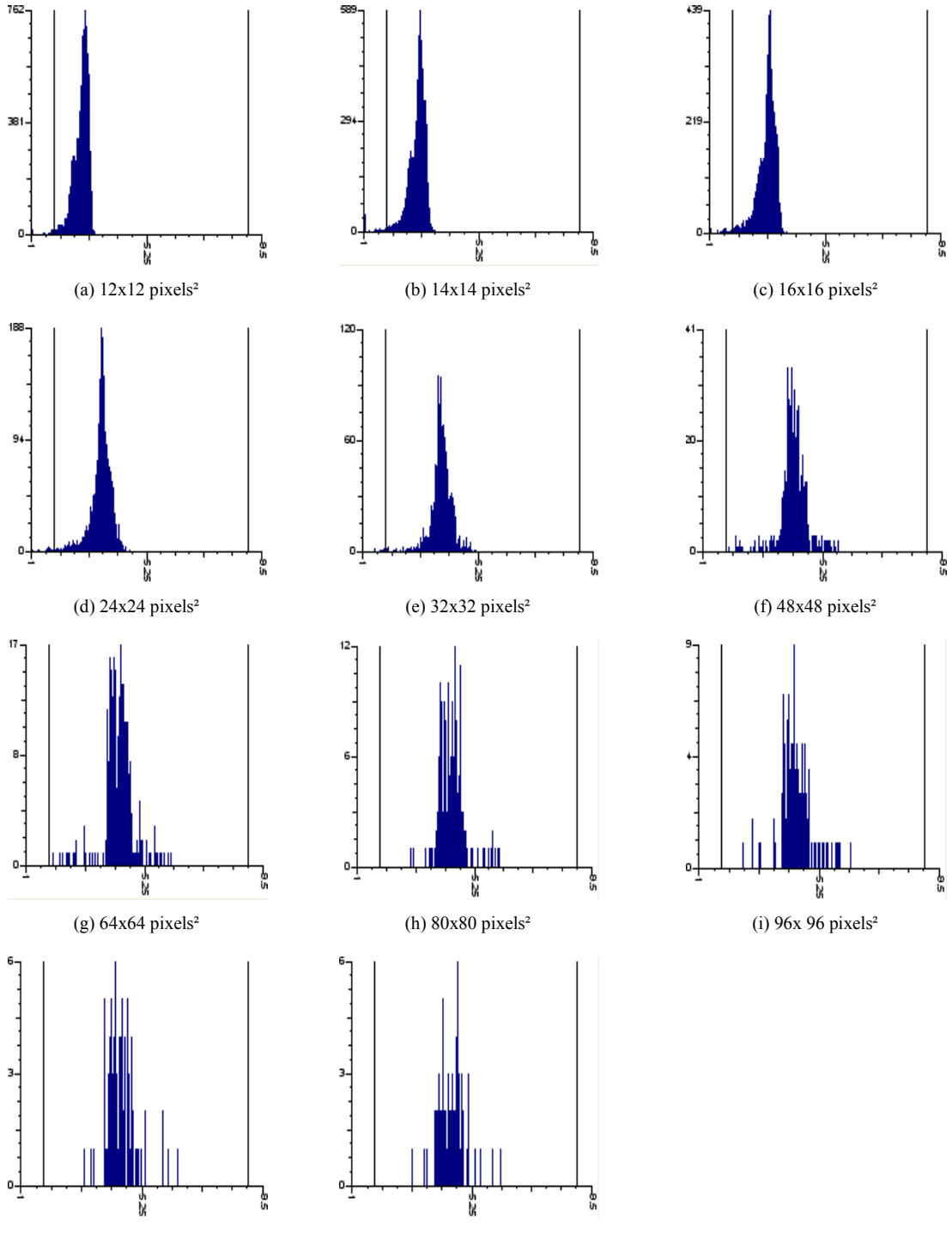
Figure 2. *Distribution of the velocity fields.*

Table 1. *Variation of the mean velocity and the vector validation with the interrogation area size.*

I (pixels)	12	14	16	24	32	48	64	80	96	112	128
Vmoy (mm/s)	32.4	32.7	33.1	33.8	34.1	32.8	31.6	29.9	29.5	28.7	29.5
Validated vector (%)	98.9	96.4	98.5	98.9	99.4	100	100	100	100	100	100

3.2. Signal to Noise Ratio Histogram

Figure 3 shows the distribution signal to noise ratio histogram for different interrogation areas sizes. According to these results, it has been noted that bumps were created for an interrogation areas size greater or equal than 48x48 pixels². In addition, it has been observed that the histogram based becomes larger when the interrogation areas size increases.



(a) 12x12 pixels² (b) 14x14 pixels² (c) 16x16 pixels²

(d) 24x24 pixels² (e) 32x32 pixels² (f) 48x48 pixels²

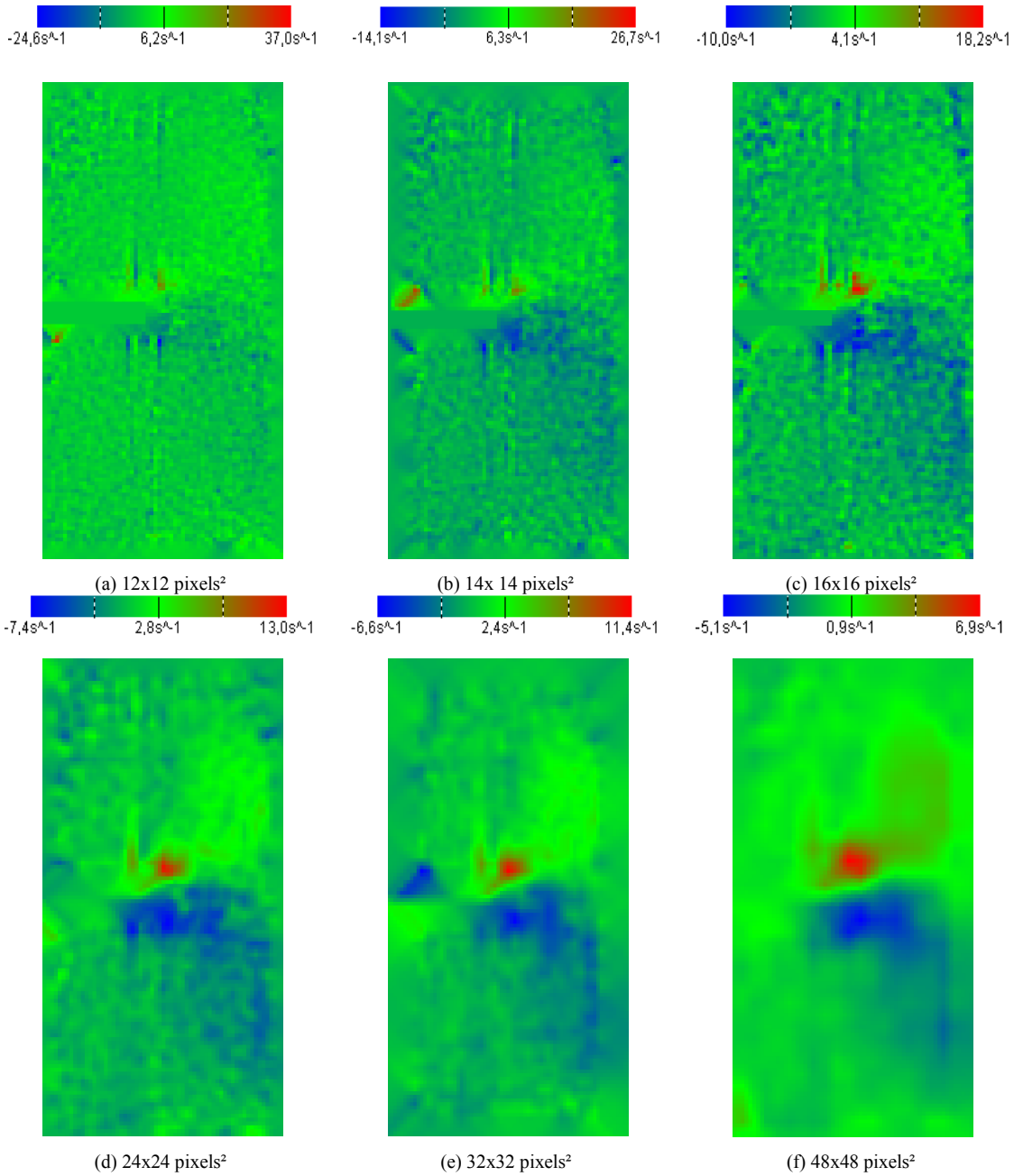
(g) 64x64 pixels² (h) 80x80 pixels² (i) 96x 96 pixels²

(j) 112x 112 pixels² (k) 128x128 pixels²

Figure 3. *Distribution of the signal to noise ratio histogram.*

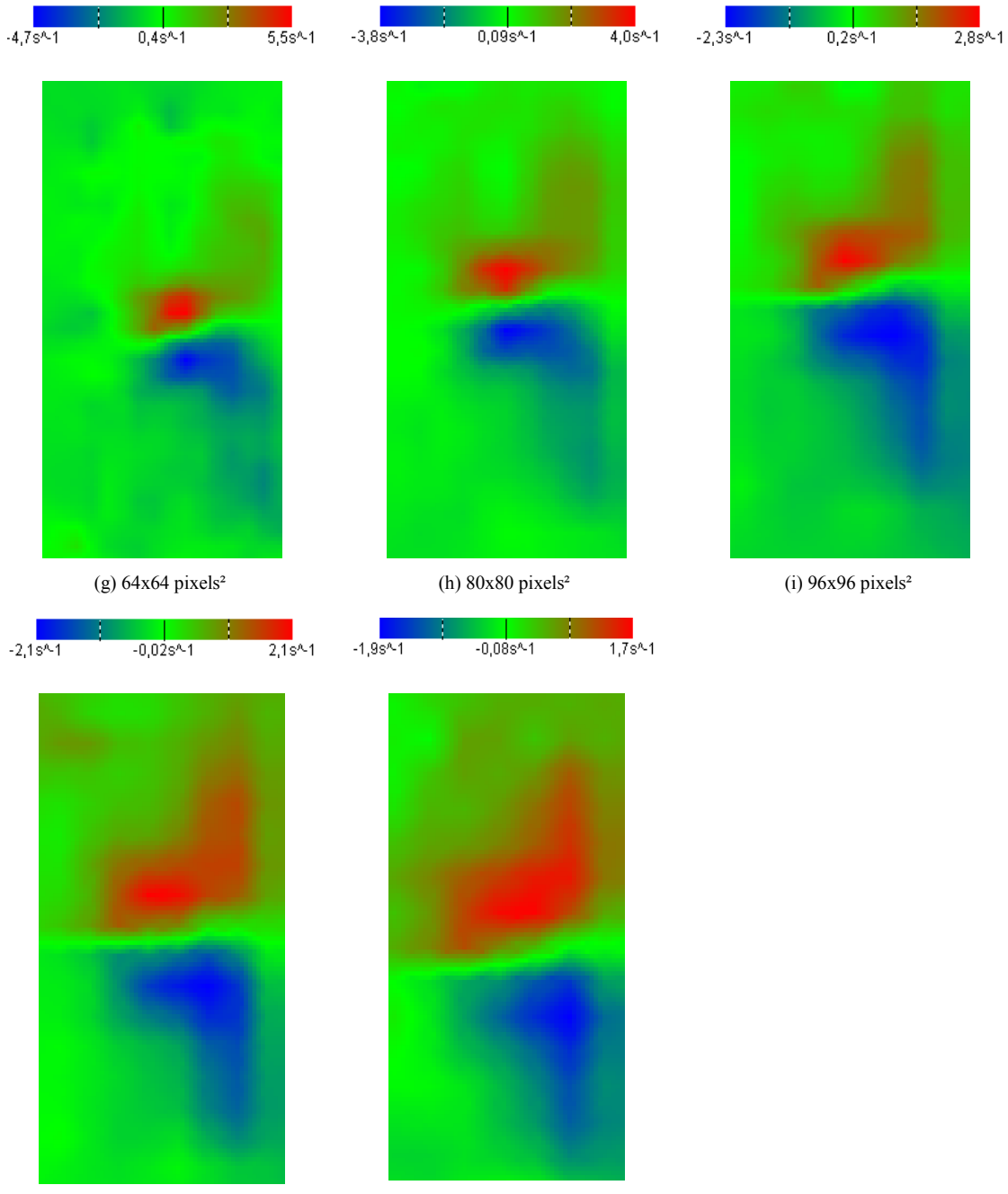
3.3. Vorticity

Figure 4 shows the vorticity distribution for different interrogation areas sizes. According to these results, it has been observed that the resolution of the distribution is affected by the interrogation areas size. Furthermore, it has been noted that the maximum values areas become larger by increasing the interrogation area size. Moreover, it has been shown that the highest vorticity value decreases by increasing the interrogation area size.



(a) 12x12 pixels² (b) 14x 14 pixels² (c) 16x16 pixels²

(d) 24x24 pixels² (e) 32x32 pixels² (f) 48x48 pixels²



(g) 64x64 pixels² (h) 80x80 pixels² (i) 96x96 pixels²

(j) 112x112 pixels² (k) 128x128 pixels²

Figure 4. *Distribution of the vorticity.*

4. Conclusions

This paper is aimed to study the interrogation area size effect on the hydrodynamics results obtained with the PIV technique. In fact, the interrogation area size was taken from 12x12 pixels² to 128x128 pixels². Velocity field, signal to noise ratio histogram and vortices were presented. Therefore, it has been observed that the mean velocity and vortices varies by varying the interrogation area size. For thus, we propose to choose an interrogation area equal to 32x32 pixels² to improve the experiments results.

In the future, we propose to study others parameters to complete these investigations.

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