The speckle image analysis by means of «chessboard» method

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Abstract: *Efficiencies of correlation methods for speckle-pictures processing and wavelet-analysis of separate image fragments processing for definition of characteristic spatial scales of speckle-pictures are discussed. For primary speckle-picture spatial scale estimation the wavelet-analysis of one or two image lines (or diagonals) well approaches. The most informative is use as base function Morle wavelet. Method lack is information loss in connection with use of a speckle-picture fragment, advantage – speed and clear interpretation. For speckle-picture processing as a whole, and also at the decision of changes in speckle-pictures under the any factor influence monitoring problems, it is expedient to use a correlation field between regular «chessboard» structure with an investigated picture calculation. This method is very sensitive – speckle size change on some pixels leads to essential correlation peaks deformation.*

Keywords: *speckle, laser, correlation, image processing, wavelet, «chessboard» structure, pixels*

INTRODUCTION

Now speckle-optics methods of liquid, solid surfaces, biological objects detection are developed. It is known, laser radiation reflecting from some object gets information about both surface and subsurface layers structure. Thus speckle-patterns contain a large amount data about size, concentration, movement speed of heterogeneities in the sample volume. On the other hand the important problem is separating useful information contained in the speckle pattern and random components caused to the presence of a many optical surfaces in schemes, unwanted light etc. For example, it is often necessary to define the characteristic (average) size of a speckle, because it is determined scattering particle size.

The aim of this work is comparing the efficiency of the correlation processing speckle-patterns technique and processing by wavelet analysis of isolated fragments to determine the characteristic (average) spatial scale of speckle-patterns.

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EXPERIMENT DATA

As the study object was selected the model media, which consist silicon carbide (SiC) particles suspended in water. The experiment used a particle with diameter of 3 μm, 10 μm, 20 μm. Speckle-patterns ware formed during the laser radiation penetrate through a transparent cell with suspension and then ware recorded on the CCD-camera.

Speckle patterns correlation analysis usually has a complex shape of the correlation function, which does not adequately define the speckle size and heterogeneity size accordingly [1].

That is why wavelet-transform method was used for express analysis. Square area 400×400 pixels were cut from source frame and then 200th line (Fig. 1) was from source frame and then 200th line (Fig. 1) was selected and wavelet transformation was applied to it.

As a mother wavelet used Morlet wavelet. The results are shown in Fig. 2 (on the horizontal axis – the pixels of the original line of speckle pattern, on the vertical axeis – the spatial scale or the characteristic size of the speckle).

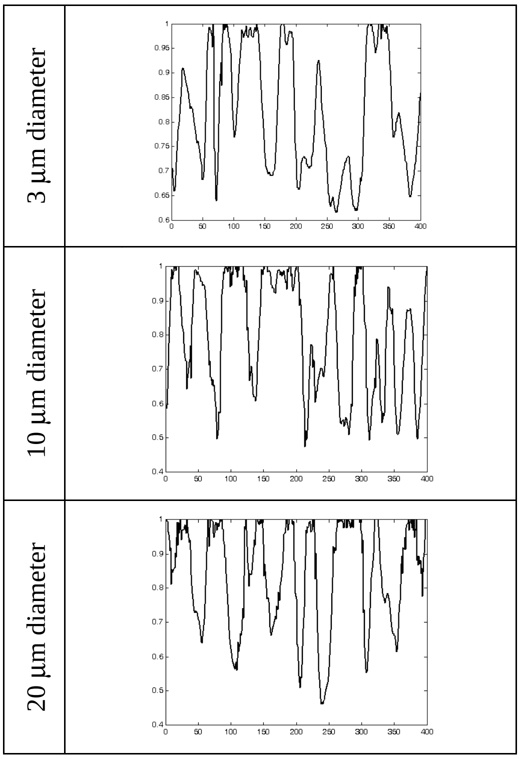

Fig. 1. Speckle patterns slice (200th line of the image matrix).

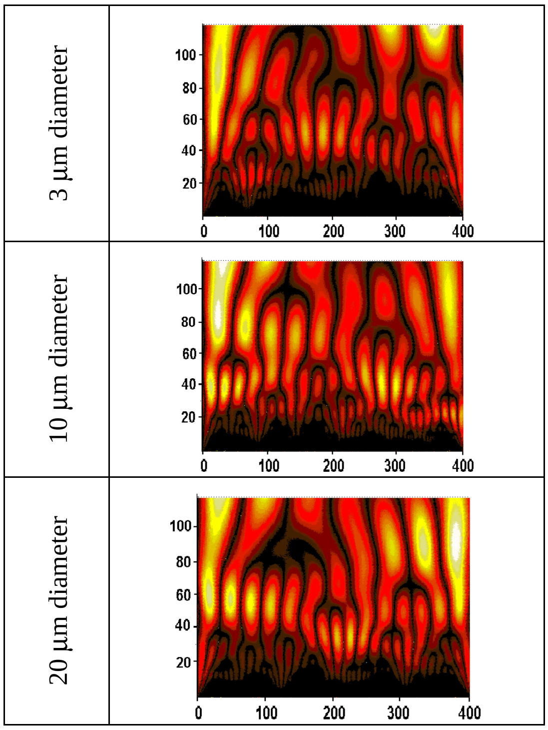

Fig. 2. Results of speckle patterns slice processing by wavelet analysis.

Wavelet analysis results comparing (Fig. 2) shows that the suspension with particles diameter of 3 µm forms a picture with two characteristic speckle sizes: about 20 pixels and 60 pixels. Speckle sizes vary from 40 to 70 pixels are observed in the speckle pattern formed by particles with a diameter of 10 µm and speckle sizes 40 to 80 pixels in the speckle pattern formed by particles with a diameter of 20 µm.

Advantages of given method are rapidity, visibility and clarity. Disadvantage is the only one line processing that can lead to loss or distortion of information contained in the speckle pattern. Also the success of wavelet analysis depends strongly on the mother function choice. If mother function is similar to intensity distribution in the speckle pattern, chance of successful result will increase.

To study granularity in photography and holography the "checkerboard" model [2-4] is used. For homogeneous space frame speckle patterns (obtained, for example, when scanning solutions in cavettos) are suggested to use this model for correlation field calculating between speckle pattern and regular structure ("checkerboard" with variable "square" size). The convolution in Fourier space and further inverse Fourier transform was calculated instead of the correlation integral direct calculation. Due the speckle sizes of the samples are in the range of 20-80 pixels, so to convolution were selected 3 "chessboard": with the "square" size 12×12, 25×25 and 50×50 pixels. The result of the correlation field calculation is the matrix of correlation coefficients, which graphically represents the surface with a set of peaks: where the correlation coefficient is bigger, there is higher peak. In our work the magnitude of the correlation coefficient is indicated by color: black is zero, white is one. The results of correlation field calculations are presented in Fig. 3-5.

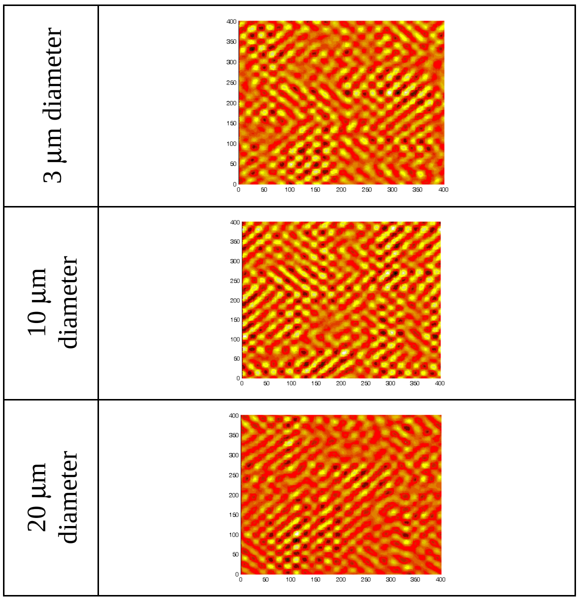

Fig. 3. Correlation field under the speckle patterns with a regular structure ("chessboard") comparing. The "square" size is 12×12 pixels.

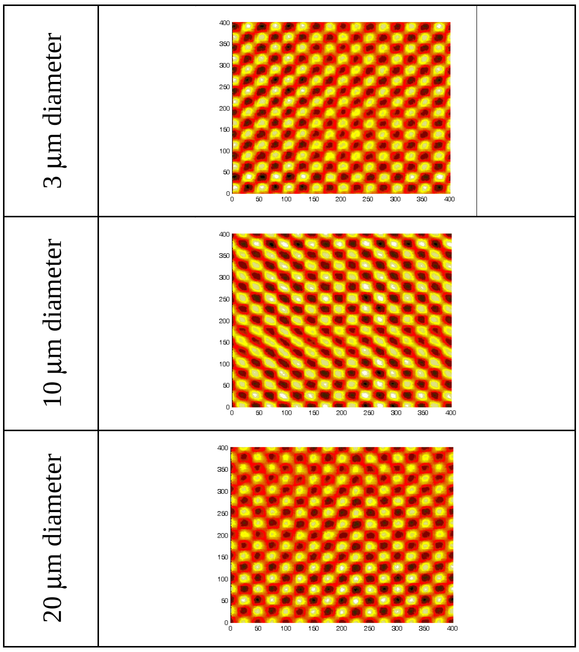

Fig. 4. Correlation field under the speckle patterns with a regular structure ("chessboard") comparing. The "square" size is 25×25 pixels.

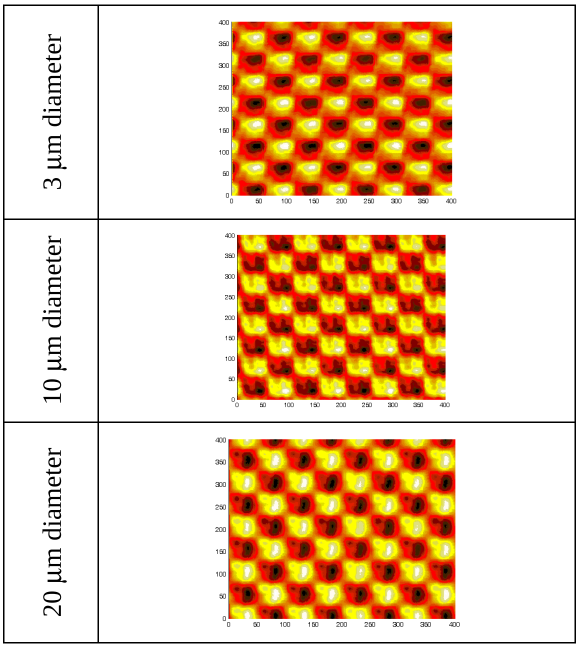

Fig. 5. Correlation field under the speckle patterns with a regular structure ("chessboard") comparing. The "square" size is 25×25 pixels.

It should be noted that if the "square" size is much smaller than the speckle, the correlation peaks are poorly expressed (in our case correlation fields contrast decreases). For example this situation occurs under calculation of the correlation field between speckle patterns and "chessboard" 12×12 (Fig. 3). If the "square" size is approximately equal to the speckle size or it is not more than 2 times, we see the connection of the correlation peaks in the chain. Finally, if the "square" size is equal to average speckle size correlation field consist of a regular rotation of the correlation peaks with correct conical shape.

Thus, characteristic (average) speckle size is 50 pixels for speckle patterns formed by suspended particles with a diameter of 3 µm. For speckle patterns formed by suspended particles with a diameter of 10 µm characteristic (average) speckle size is 30-40 pixels. And for speckle patterns formed by suspended particles with a diameter of particles 20 µm characteristic (average) speckle size is about 25 pixels.

These data are in good agreement with the spatial scale obtained by the wavelet analysis method. Also, suggested correlation method allows to define both the speckles size and their localization in the speckle pattern. Additionally, the correlation field calculating uses all of the information contained in the speckle pattern.

As an illustration of the correlation method application for the analysis of changes in the speckle-paintings we demonstrate experiment results obtained under laser treatment for gasoline (radiation source is helium-neon laser, radiation intensity is about 100 mW/cm^2). The correlation fields calculated between speckle pattern and "chessboard" with different scale are presented in Fig. 6-8.

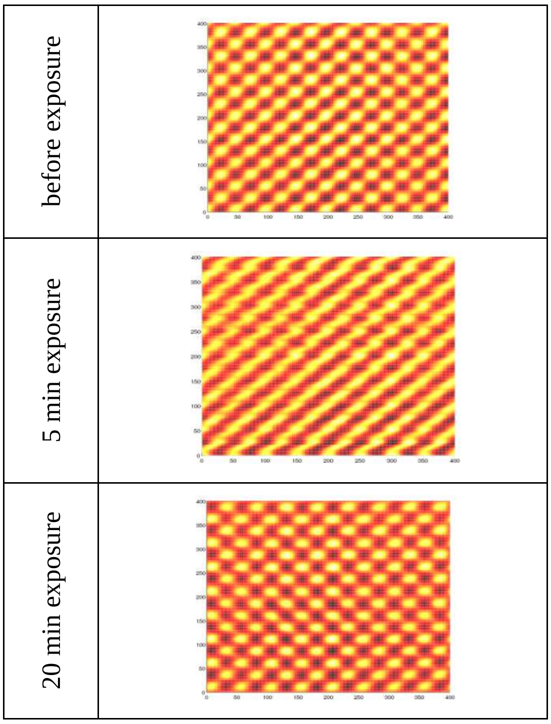

Fig. 6. Correlation field under the speckle patterns from gasoline with a regular structure ("chessboard") comparing. The "square" size is 25×25 pixels.

Analyzing Fig. 6, we can conclude that before exposure prior speckle pattern from gasoline has characteristic speckle size 25-30 pixels because the most clear correlation peaks are observed for convolution with a "chessboard" 25×25 pixels. However, slightly elongated shape of the peak indicates that the speckle size several more then "square" size.

After 20 minutes of laser radiation exposure the characteristic speckle size grows to 40 pixels, which is indicated by the right conical form of the correlation peaks in the convolution with the "chessboard" 40×40 pixels. The heterogeneity size is inversely proportional to the speckle size. If we know numerical data of experiment geometry and speckle size, we can calculate the characteristic (average) size of gasoline cluster. Approximate calculation show that heterogeneity size decreased from 80 μm to 50 μm under action of laser radiation on gasoline.

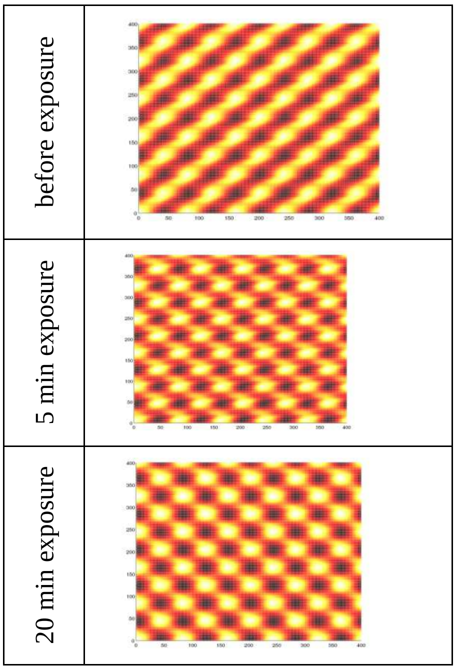

Fig. 7. Correlation field under the speckle patterns from gasoline with a regular structure ("chessboard") comparing. The "square" size is 40×40 pixels.

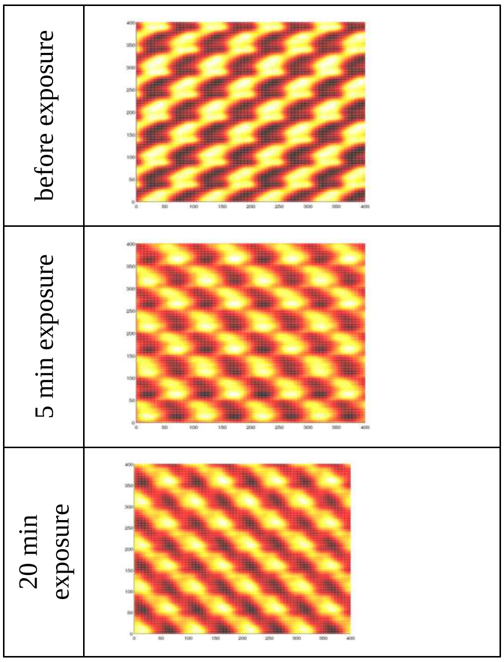

Fig. 8. Correlation field under the speckle patterns from gasoline with a regular structure

CONCLUSION

Thus, conclusions are following:

1. For the initial estimation of the characteristic (average) spatial scale of the speckle pattern is well suited wavelet analysis method for one or two image lines (or diagonals). The disadvantage is the information loss caused by using of a speckle pattern fragment. The advantage is rapidity, visibility and clarity of interpretation.

2. For the general speckle pattern processing and for monitoring of changes in the speckle-patterns under some action we suggest the calculation of the correlation field between the regular structure ("chessboard") with the investigated pattern. This method is very sensitive, because the change of the speckle size by a few pixels, leads to significant deformation of the correlation peaks.

3. The proposed method application to a real fluid on the example of gasoline has allowed to reveal, that under the laser irradiation in gasoline structural changes is occurred. The reduction of the characteristic (average) size of gasoline cluster in 1,5-2 times lead to speckle size increasing and significant changing in correlation fields.

("chessboard") comparing. The "square" size is 50×50 pixels.

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