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BIG CONSTRUCTIONS DISPLACEMENT AND DEFORMATION MEASUREMENT BY WHITE LIGHT SPECKLE PHOTOGRAPHY

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1. Introduction

A number of displacement and deformation measurement methods exist, based on registration and processing of the studied speckle images [1]. These images have a fine structure of bright spots (speckles), casually distributed over a dark background. The speckle pattern may be obtained, when a rough surface is illuminated by coherent light [2], as well as through the image of a rough surface or surface with white spots, painted on a dark background and illuminated by a source of light of low degree of coherence, i.e. – a "white light" source [3]. As shown in ref.[4] and [5], the white light speckle photography has a good potential in the case of its application in measuring of large object displacement and deformation fields. But in these two studies the optical system (usually – lenses) is situated at a distance not more than 5 meters and not less than 6000 meters respectively from the object investigated. In [4] "white light" speckle photography is used in the case of glacier movement studies. The object is illuminated by sun light and is imaged by lenses of focal lengths 916 mm and 500 mm from a distance of about 6000 meters.

The aim of the present work is to study the upper and lower limits of the measurable displacement using white light speckle photography with conventional lenses and special prepared diffusers. The distances between lenses and diffusers vary in the interval from 4 meters to 60 meters.

2. Experiments and experimental results

The main parameter which determinates the sensitivity of white light speckle photography in the case of fixed image system magnification is the average diameter of the observed surface of the structural elements. This parameter is related to the average speckle size [4]. The variation of the spots sizes gives a possibility to control white light speckle photography sensitivity using suitable diffusers, which are fixed over the investigated surface.

Two types of special made diffusers were used. One of them consists of aluminum particles of average sizes 1 mm (diffuser D_1), 0,8 mm (diffuser D_2) and 0, 5 mm (diffuser D_3). The particles are sprinkled over a dark surface of a plate and are fixed to it by means of a thin epoxy layer. The other type of diffusers — D_4 have a plane surface of aluminum plate, washed by retropaint and covered with a dark mask. Circular holes with diameters 5 mm, 2 mm and 1 mm are bored in the mask. The distribution of these holes over the mask surface is accomplished by a computer, according to a statistical normal distribution low.

A series of specklegrams are taken to define the optimal conditions for their registration applying all possible combinations of diffusers, prepared, and different positions of the light source with respect to the diffusers in the case of three lenses of focus length respectively f_1 - 58 mm, f_2 - 135 mm and f_3 - 186 mm. The diffusers were fixed, but the lenses with a photo camera sticked to each of them were translated in a plane, parallel to diffuser's plane by means of a single axis stage with micrometer. The object was illuminated by a white light source - a conventional lamp.

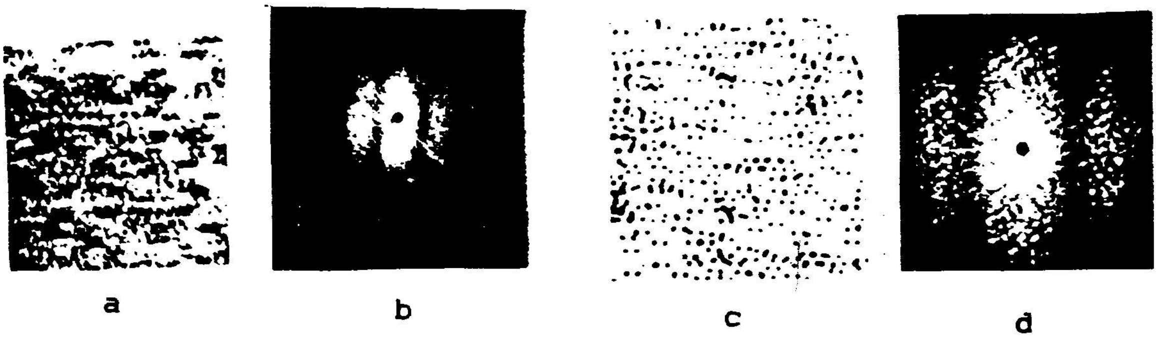

Fig. 1

A photo of diffusers D_1 specklegram micro structure is shown in Fig. 1-a. This image is obtained by an objective of f_2 = 135 mm. The distance between the objective and the diffuser is 10 m., the microscope magnification being 80×. Young's fringes, obtained after diffraction of a nonexpanded laser beam on the specklegrams are shown

Table 1

L [m]	f [mm]	diff.	m	δ [μm]	l_{min} [mm]	l_{max} [mm]	$\Delta l/l$
4	58	D_1	0,015	14	0,90	12,0	0,036
4	58	D_2	0,015	10	0,60	12,0	0,034
4	58	D_3	0,015	6	0,40	12,0	0,033
4	58	D_4	0,015	12	0,70	12,0	0,010
5	135	D_1	0,029	20	0,67	6,2	0,031
5	135	D_2	0,029	16	0,54	6,2	0,027
5	135	D_3	0,029	12	0,40	6,2	0,025
5	135	D_4	0,031	17	0,23	5,8	0,019
5	186	D_1	0,037	31	0,84	4,9	0,032
5	186	D_2	0,037	23	0,63	4,9	0,027
5	186	D_3	0,037	8	0,21	4,9	0,024
5	186	D_4	0,037	30	1,00	4,9	0,021
10	58	D_4	0,006	6	1,00	30,1	0,027
10	135	D_1	0,012	16	1,25	15,6	0,040
10	135	D_2	0,012	12	1,00	15,6	0,038
10	135	D_3	0,012	8	0,70	15,6	0,038
10	135	D_4	0,014	10	0,70	12,9	0,017
10	186	D_1	0,016	13	0,85	11,3	0,035
10	186	D_2	0,016	13	0,85	11,3	0,033
10	186	D_3	0,016	8	0,49	11,3	0,032
10	186	D_4	0,019	10	0,50	9,5	0,017
15	58	D_4	0,004	8	1,95	45,2	0,038
15	135	D_4	0,009	12	1,30	20,1	0,019
15	186	D_1	0,012	12	1,00	15,6	0,040
15	186	D_2	0,012	12	0,70	15,6	0,038
15	186	D_4	0,012	8	1,00	15,6	0,017
20	135	D_4	0,007	10	1,40	25,8	0,250
20	186	D_4	0,009	10	1,10	20,1	0,190
25	135	D_4	0,006	6	1,00	31,1	0,030
25	186	D_4	0,007	10	1,40	25,8	0,026
30	135	D_4	0,004	8	1,95	45,2	0,034
30	186	D_4	0,006	6	1,00	31,1	0,029
35	186	D_4	0,005	6	1,20	36,0	0,028
40	186	D_4	0,005	4	0,80	36,0	0,034
45	186	D_4	0,004	4	1,00	45,0	0,035
50	186	D_4	0,004	4	1,00	45,0	0,037
55	186	D_4	0,003	4	1,30	60,0	0,040
60	186	D_4	0,003	4	1,30	60,0	0,045

in Fig. 1-b. According to [4], the smallest measurable displacement, registered in the specklgram is the one, in which first Young's fringes diffraction order fits into the diffraction halo boundary. Having in mind this criterion we may determine the lower limit of the measurable displacement. For the first type diffuser's double exposure registration this limit is about 1 mm. In Fig. 1-c a micro photo of specklegram, obtained from the D_4 type diffuser is shown. In this case the specklegram is registered by means of objective of $f_1 = 58$ mm and magnification 0,006. The respective Young's fringe pattern is presented in Fig. 1-d. We can see that the diffraction fringes, obtained in white light speckle photography show a good contrast. The automatic measurement of the fringe pattern parameters may be carried out with a good accuracy [6]. These fringes were obtained when the light source position was near to the imaging lens for diffusers $\mathbf{D}_4$ and near to the diffusers plane for diffusers' $\mathbf{D}_1, \mathbf{D}_2$ and $\mathbf{D}_3$ respectively. The optimal angle between the diffusers $\mathbf{D}_1 - \mathbf{D}_3$ plane and the direction from the source is about about 30°.

Taking into account the above mentioned optimal registration conditions, the possible combination of the pairs diffuser – objective were chosen, varying the distance between them from 4 to 60 meters. The results from these experiments are given in Table 1, where – **L** is the object distance, **f** – the focal length of the objective used, **m** – the magnification (the scale coefficient), δ – the average diameter of the spots over the specklegram, measured by a microscope, $\mathbf{l}_{min}$ and $\mathbf{l}_{max}$ – the minimum and the maximum displacement measured, $\Delta \mathbf{l}/\mathbf{l}$ – the measurement error.

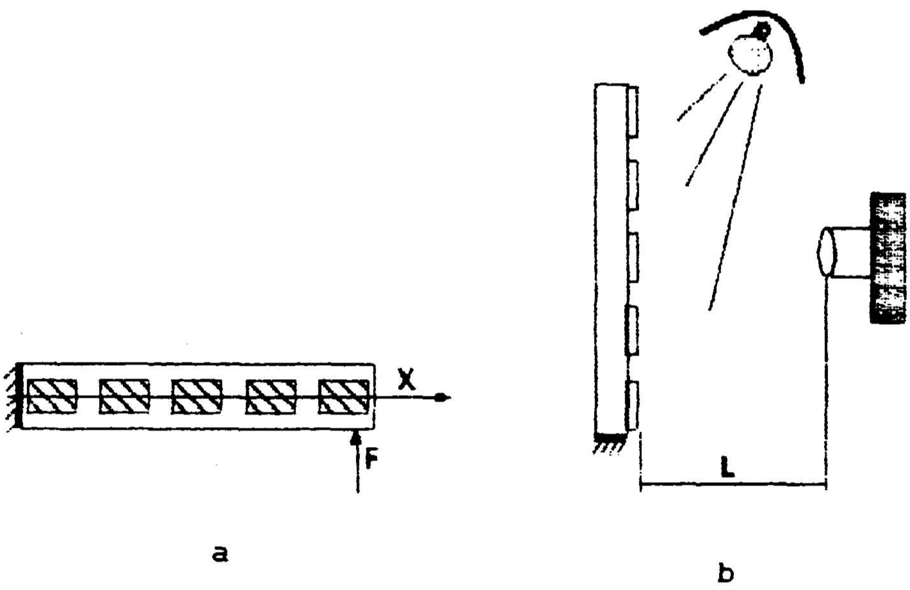

Fig. 2

The acquired in this way knowledge and abilities have been applied to measure the displacements in five points on the axis of a wood beam (Fig. 2-a) which length is 180 cm and the crossection 18 cm ×18 cm, due to the bending. A lens ($\mathbf{f}_2 = 135$ mm) and the five diffusers of the $\mathbf{D}_1$ tipe are used, the distance **L** being 10 meters. The diffusers are illuminated by a lamp (Fig. 2-b). At the same time, the displacements in these five points are being measured by five dial gauges. The results from this experiment are presented graphically in Fig. 3, where **d** is the displacement measured, **x** – the distance from each diffuser to the fixed beam's end, o – the results from white light speckle-photography measurement, Δ – the contact indicators measurements results. Because of some difficulties of fixing, in the cases of bigger deformations (the upper curves in Fig. 3) the dial gauges give no information.

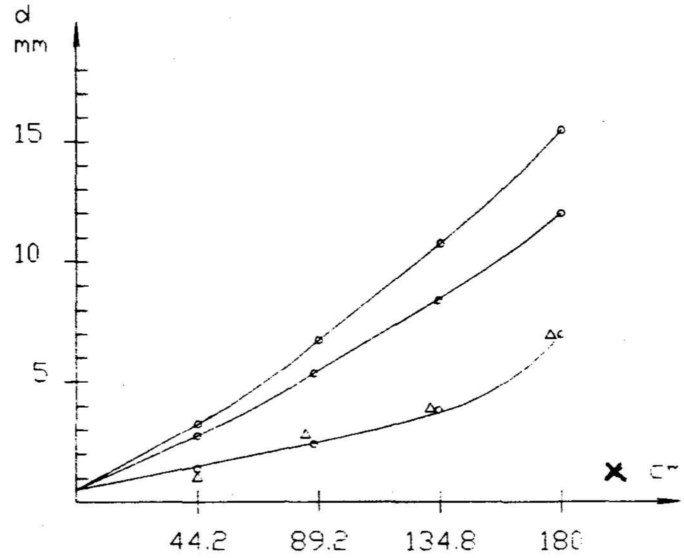

Fig. 3

3. Conclusion

The results from the above presented experimental study show that white light speckle photography may be used successfully in noncontact displacement measurements in the solution of a number of problems, connected with large object deformations in the fields of building mechanics, exploitation of hoists etc. When conventional lenses and special diffusers are used, the sensitivity of this optical method may be controlled from 0,6 mm at the distance of 5 m, to 1,0 mm at a distance of about 60 m.

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