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Fabrication of Micro-Scale Speckles with Particle Dispersion Method

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Abstract: Micro-scale speckles with particle dispersion method are fabricated as the deformation carriers in the digital image correlation method. Micro-scale carbon particles are mixed with epoxy resin proportionally, followed by solidifying, centrifugal and spinning. In the end, a speckle film can be fabricated, which can be transferred to the surface of specimen. The quality of speckles is evaluated by the average gray gradient and the fabrication parameters including solidifying time, centrifuge speed, and spinning rate are studied and optimized.

Keywords: Micro-Scale Speckle, Digital Image Correlation Method, the Average Gray Gradient, Optical Measurement Mechanics

1. Introduction

Digital image correlation method (DIC) [1] is a non-interferometric optical technique, and has been widely used as a powerful and flexible tool for the surface deformation measurement in the field of experimental solid mechanics. As a carrier of deformation information, speckle is one of the most important elements and the measurement accuracy is affected by its quality. With the development of micro-scale materials and devices [2], mechanical testing in micro-scale is particularly important, which provides new challenges for fabrication of micro-scale speckles.

As for the fabrication of speckles, the artificially spraying black and white paints has been commonly used for fabrication of speckles in macro-scale. In addition, there are various methods to fabricate speckles in nanoscale, such as spraying method [3], chemical deposition method [4], nano-imprinting [5] etc. However, there are few researches on fabrication of micro-scale speckles [6]. In the present contribution, fabrication of micro-speckles is proposed using the method of centrifugal and spinning of epoxy solution mixed with particles with size of about 10 um. To the best knowledge of authors, little attention has been pay to the study of fabrication technique of micro-scale speckles in the present contribution. With the development of micro-scale materials and devices. The fabrication of micro-scale speckles is more and more important [6]. We have developed in our study a novel and effective method for fabrication of micro-scale speckle pattern. The speckle pattern distribution density is varied with the spinning rates and the proportion of epoxy resin and powder particle. We have changed the fabrication parameters to improve the quality of speckle pattern, which is evaluated by average gray gradient. In the study we have found a peak value of average gray gradient under solidifying time, centrifugal velocity, spinning rate.

2. Fabrication Method

The fabrication method of micro-scale speckles can be divided into five steps. (1) Carbon particles were selected according to the observation by scanning electron microscopy and were mixed with epoxy solidifying agent solution; (2) Eliminating bubbles from the compound using a centrifuge to avoid reunion of particles; (3) Dispersing and fixing the compound on the surface of the sample using a spin processor; (4) Hard baking to enhance particle adhesion to the surface of the sample; (5) Checking the speckle pattern under optical microscopy and optimizing the patterning technique. Figure 1 is a micro speckle production process.

As for speckle quality evaluation, global and local parameters are generally accepted. Local parameters including sub-region entropy [7], the gray intensity gradients, mean subset fluctuation [8]. Global parameters include average speckle size [9], speckle noise [10], the average gray gradient

[11]. In the present study, the method of average gray gradient (AGG) is adopted for speckle quality evaluation because it is simple and effective [11].
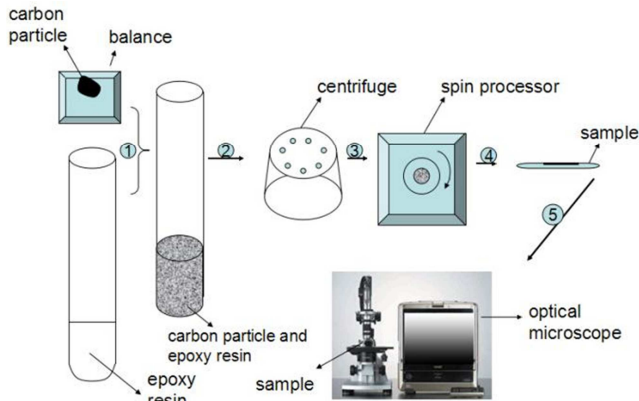

Figure 1. *Flow chart of fabrication technique of micro-scale speckles.*

3. Results and Discussion

3.1. Effect of Solidifying Time

Figure 2 shows the speckle images under different solidifying times. Figure 3 demonstrates the relation of solidifying time and average gray gradient of the speckle pattern. The magnitude of AGG increases with the increasing of solidifying time from 5 min to 15 min. It has the maximum value at the time of 15 minutes, which manifests that the speckle pattern is of the best quality. After that, the magnitude of AGG goes down with the increasing of solidifying time.

Apparently, the viscosity of epoxy solution goes up with the solidifying time. Sparse particle patterns appear when the solidifying time is short and the viscosity of epoxy solution is low. On the opposite, particles reunite when the solidifying time is too long and the viscosity of epoxy solution is high. Therefore, there is an optimum solidifying time for the viscosity of epoxy solution to obtain a speckle pattern with the highest AGG.
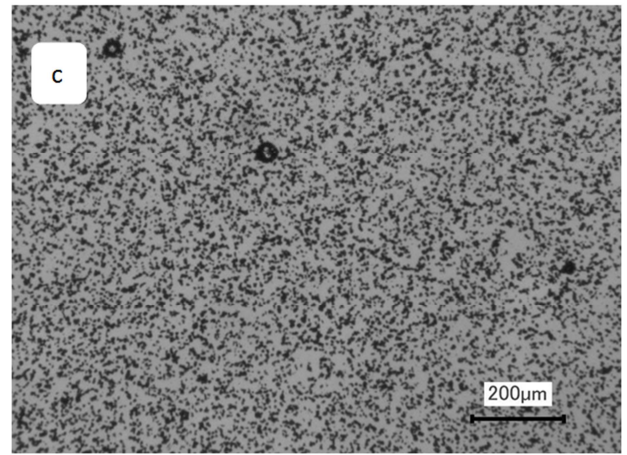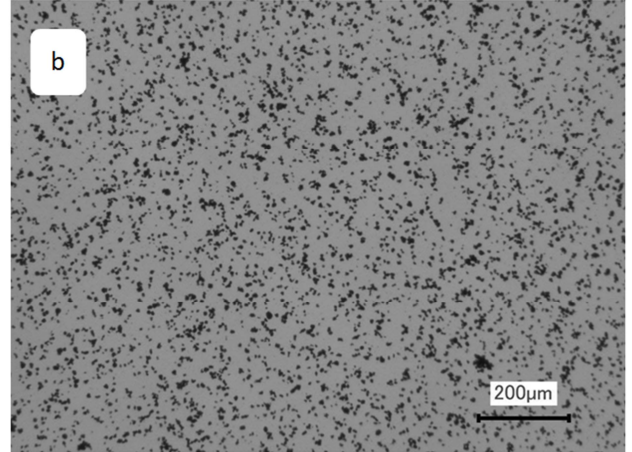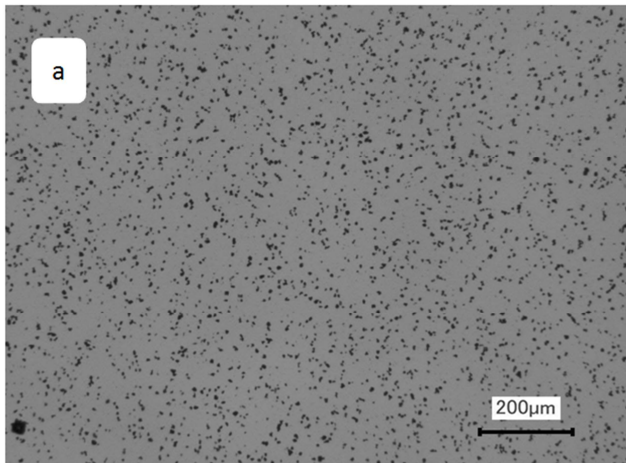

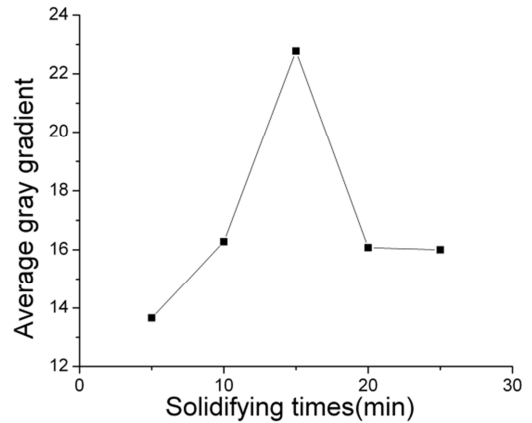**Figure 2.** *Pattern distribution under different solidifying times: (a)5min, (b)15min, (c)25min.*

Figure 3. *Relation of solidifying time and AGG of speckle pattern.*

3.2. Effect of Centrifugal Velocity

Figure 4 demonstrates the relation of centrifugal and average gray gradient of the speckle pattern. The magnitude of AGG increases with the increasing of centrifugal velocity from 500 rpm to 1000 rpm. It has the maximum value at the centrifugal of 1000 rpm, which manifests that the speckle pattern is of the best quality. After that, the magnitude of AGG goes down with the increasing of centrifugal velcity.

The study found that the increase of centrifugal velocity will reduce the reunion, but the AGG values will decline. When the epoxy solution mixed with the powder particles will produce a lot of tiny gas bubbles in the process of spinning. It will affect the quality of the speckle pattern, it is necessary to use centrifugal to remove air bubbles, the centrifugal speed also has a relationship with the powder reunion rate, where it is necessary to look at the impact of the size of the centrifugal speed to effects of AGG and reunion rate. Centrifugal velocity used in the experiment were 500, 1000, 1500, 2000, 2500 rpm.
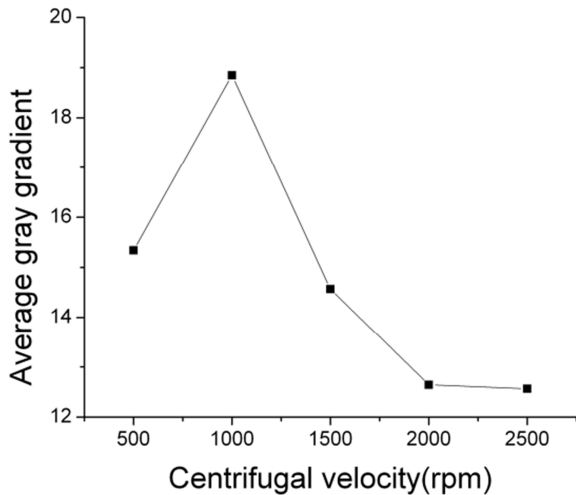

Figure 4. Relation of centrifugal velocity and AGG of speckle pattern.

3.3. Effect of Spinning Rate

Figure 5 shows the speckle images under different spinning rate. The speckle quality was studied with AGG value when the spinning rate was from 1000 rpm to 3500 rpm. Figure 6 shows that the speckle pattern with the largest AGG is produced at a rate of 3000 rpm. The average gray gradient of the speckle image is not optimum if the spinning rate is higher or lower than 3000 rpm. Hence, we take 3000 rpm spinning rate as the measured rate in the following experiments.
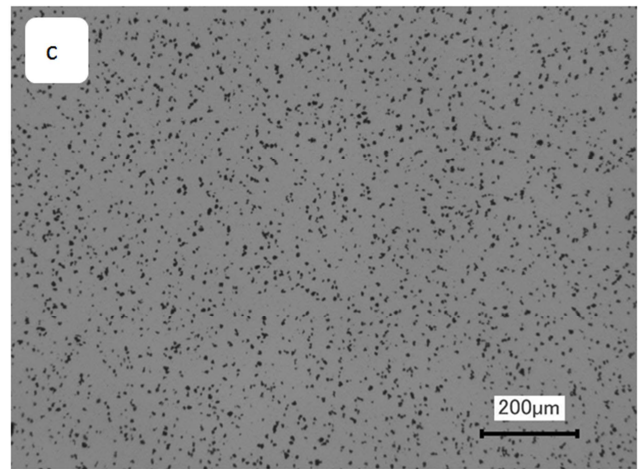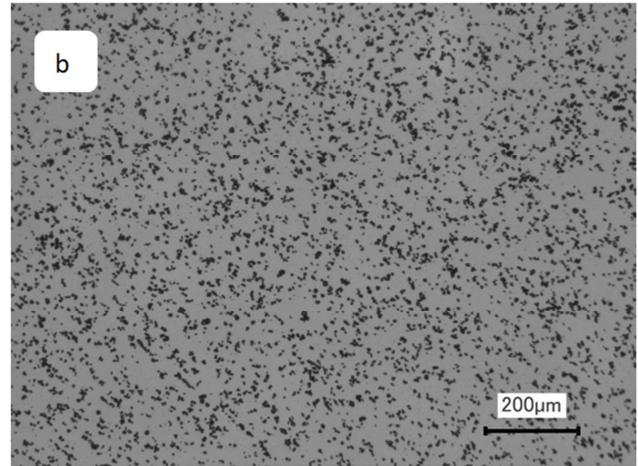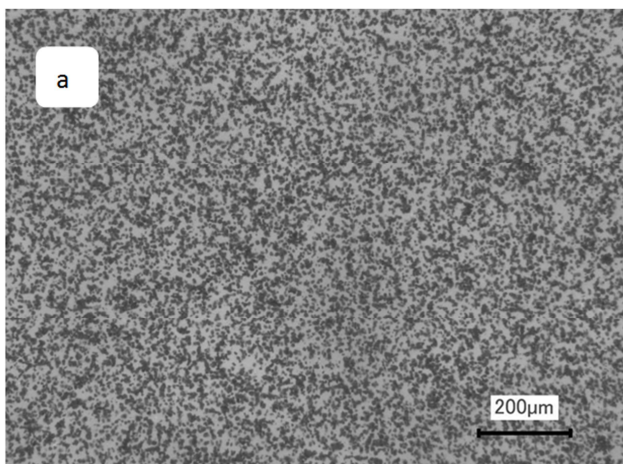

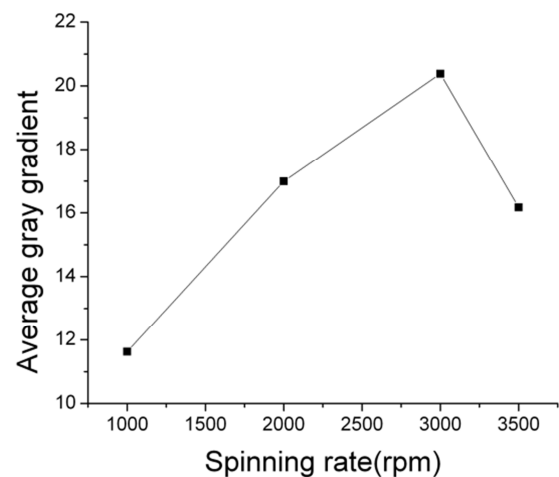*Figure 5. Pattern distribution under different spinning: (a)1000rpm, (b)3000rpm, (c)4000rpm.*

Figure 6. Relation of spinning rate and AGG of speckle pattern.

Spinning rate will affect the distribution of particles in solution, spin too fast will throw the scattered particles can prevent reunion. But the speed is too fast, then the particles will be relatively sparse distribution, the AGG will drop, so here it is necessary to examine the impact of the size of the spin coating speed to effect of speckle pattern quality.

4. Conclusions

A fabrication method for micro-scale speckles using particle dispersion is proposed. Experimental studies show that the speckle quality is influenced by fabrication parameters including solidifying time, centrifuge speed, and spinning rate. It is concluded that the optimal speckle pattern can be attained under the following conditions: the proportion of epoxy resin and powder particles—3 ml: 0.2 g, spinning solidifying time—15 min, centrifugal velocity—1000 rpm and spinning rates—3000 rpm. The results manifest that the method has advantages of experimental equipment simple, easy to implement, well control the distribution of the speckle pattern and solve problems reunion eliminate lumps.it can create different density of speckle patterns.

In addition, for different surface measurements need to select different particles, so that these parameters may also be changed.

Acknowledgements

References

[1]   W. H. Peters and W. F. Ran son, "Digital imaging techniques in experimental stress Analysis," Opt. Eng. Vol. 21, pp. 427-31, 1981.

[2]   Berfield T A et al. "Micro- and nanoscale deformation measurement of surface and internal planes via digital image correlation" Exp. 51–62, Mech. 200.

[3]   Sun Z L, Lyons J S, McNeill S R, "Measuring microscopic deformations with digital image correlation," Optics and Lasers in Engineering, vol. 27, pp. 409–28, 1997.

[4]   Scrivens W A, Luo Y, Sutton M A, et al. "Development of Pattern for Digital Image Correlation Measurements at Reduced Length Scales," Exp. Vol. 47, pp. 63-77, Mech. 2007.

[5]   Collette S A, Sutton M A, et al, "Development of pattern for nanoscale strain measurements: I. Fabrication of imprinted Au webs for polymeric Materials," Nanotechnology, 15: 1812-1817, 2004.

[6]   H. X. Wang, H. M. Xie, Y. J. Li and J. G. Zhu, "Fabrication of micro-scale speckle pattern and its applications for deformation measurement," Measurement Science and Technology, 23: 035402, 2012.

[7]   Sun Y F, Pang H J. "Study of optimal subset size in digital image correlation of speckle pattern images," Optics and Lasers in Engineering, 45: 967–74, 2007.

[8]   Hua T, Xie H M, Wang S, et al. "Evaluation of the quality of a speckle pattern in the digital image correlation method by mean subset fluctuation," Optics and Laser Technology, 43: 9–13, 2011.

[9]   Lecompte D, Smits A, Bossuyt S, et al. "Quality assessment of speckle pattern for digital image correlation," Optics and Lasers in Engineering, 44: 1132–45, 2006.

[10] Y. Q. Wang, M. A. Sutton, H. A. Bruck, et al. "Quantitative error assessment in pattern matching: effects of intensity pattern noise, interpolation, strain and image contrast on motion measurements," Strain, 45: 160–78, 2009.

[11] B. Pan, Lu Z X, Xie H M. "Mean intensity gradient: An effective global parameter for quality assessment of the speckle pattern used in digital image correlation," Optics and Lasers in Engineering, Vol. 48, pp. 469–477, 2010.