Lateral vibrations measurement of powdery clay sample using speckle photography

Buah-Bassuah, P.

P. K. Buah-Bassuah, "Lateral vibrations measurement of powdery clay sample using speckle photography," Proc. SPIE 2778, 17th Congress of the International Commission for Optics: Optics for Science and New Technology, 27784N (1 September 1996); doi: 10.1117/12.2299049

Event: 17th Congress of the International Commission for Optics: Optics for Science and New Technology, 1996, Taejon, Korea, Republic of

LATERAL VIBRATIONS MEASUREMENT OF POWDERY CLAY SAMPLE USING SPECKLE PHOTOGRAPHY

P.K. BUAH-BASSUAH AND E. AMPEM-LASSEN

LASER AND FIBRE OPTICS CENTRE (LAFOC)
DEPARTMENT OF PHYSICS
UNIVERSITY OF CAPE COAST
CAPE COAST, GHANA

ABSTRACT

We report the use of lateral vibration of speckle patterns in studying the particle sizing of bulk powdery clay sample. A two-exposure recording was made on a high-resolution holographic plate placed in the observation plane. The first exposure was taken when the laser-speckles without the sample vibrated laterally and the second when the laser-speckles and the sample vibrated laterally together. The plate was photographically processed to obtain a specklegram. The analysis of the fringe pattern from the decoded specklegram gave the particle sizes in the sample.

INTRODUCTION

Speckle photography is a technique for sensitive measurements in optical metrology.[1]. The double-exposure speckle pattern recording or speckle photography has been used in velocity [2], refractive index [3], vibration [4], small displacements [5], rough surface [6], and other measurements [7, 8]. The study of the lateral vibrations of the speckle field obtained from vibrating powdery clay sample using the technique of speckle photography leads to the determination of the particle size distribution of the bulk powdery sample.

THEORY

When laser light is scattered by a rough surface with a diameter d towards an observation screen or photograhic plate at a distance z, the scattered light is randomly phased; bright intensity spots are produced which characteristic size (radius r) is expressed as $r = 1.22\frac{\lambda}{d}z$ where λ is the wavelength of the incident beam. At any point in the observation plane, the irradiance of the speckle pattern formed by the double exposure of the speckle field alone , and also together with the sample when laterally vibrated have corresponding point in the particle displaced by a small amount $\vec{L}$. The resulting phase difference, $\Delta\phi$, is changed by an amount γ given by $\gamma = (\vec{k}_2 - \vec{k}_1)\cdot\vec{L}$ where $\vec{k}_1$ and $\vec{k}_2$ are the propagation vectors of the two illuminations from the speckles and the displaced sample particles. The developed plate can be examined in one region at a time by illuminating it with unexpanded HeNe laser beam. Since these regions contain pairs of identical speckles, the speckle pattern will diffract the beam into diverging cones. The light in the resulting pairs of diffraction cones will interfere to form a diffraction pattern modulated by Young`s fringes. The fringe spacing s thus defines a diffraction angle ϑ along the distance D between the specklegram and the observation plane according to $\tan\vartheta = \frac{s}{D}$ whilst the pitch of the specklegram is given by $\sin\vartheta = \frac{\lambda}{D}$. The two-exposure technique produces twin on-axis speckles at a height h from the axis giving a speckle pattern of a separation distance, δ, which is a function of the height h. By geometrical considerations, the displacement Δz of the powdery sample is obtained from $\Delta z = \frac{z}{h}\delta(h)$ and $\delta(h) \cong \frac{\lambda}{s}\frac{D}{h}$.

EXPERIMENTAL ARRANGEMENT AND RESULTS

From figure 1, the diffuser was placed on a white card which was mounted on the membrane of the loud speaker, illuminated by an unexpanded 5mW HeNe laser of wavelength (λ = 632.8nm) and masked by a circular aperture ofdiameter d = 20mm. The loud speaker was then connected to an amplifier and a signal generator which was driven by an AC source. For a safer recording, a holographic Agfa Holotest 8E75 was placed 250 mm from the diffuser for recording the speckle patterns, in order to obtain a fine grain scatterer since the sensitivity of measurement require that the speckle motion in the observation plane should exceed the characteristic speckle size. Two different double-exposures were taken. In the first instance, the plate was exposed twice to the generated speckles, once when the speckles were stationary and once when the speckles were in lateral vibration.

17th Congress of the International Commission for Optics: Optics for Science and New Technology,
edited by Joon-Sung Chang, Jai-Hyung Lee, ChangHee Nam, Proc. of SPIE Vol. 2778, 27784N

In the second case, the plate was twice exposed to the speckles in motion, once when the speckles were laterally vibrating without the sample, once when the speckles and the sample were together in lateral vibration. The two plates were photographically processed to produce specklegrams 1 and 2. The specklegram on which was normally incident an unexpanded HeNe laser beam was mounted on a micrometric translation stage at 100cm away from the screen. In order to measure s and h, by making use of the translator, the specklegram 1 was displaced horizontally from the center where no fringes were present towards the right direction until fringes were seen. The pitch s of the fringes were measured with a vernier caliper and h_1 with the micrometer of the translator. The translator was moved in the opposite direction to recover the plate centre towards the left direction until fringes of the same pitch s were again seen. The second reading h_2 of the micrometer was recorded. The height, h, was evaluated from $h = (|h_2 - h_1|)/2$. The distance of separation between the specklegram and the screen were measured with a metre rule.

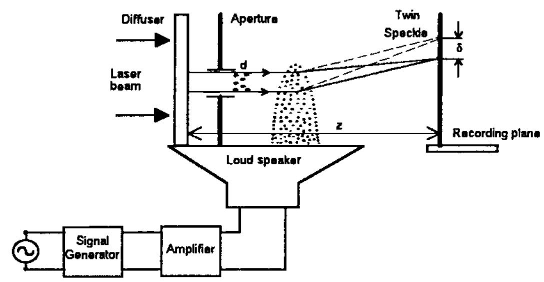

Fig. 1.) The experimental setup

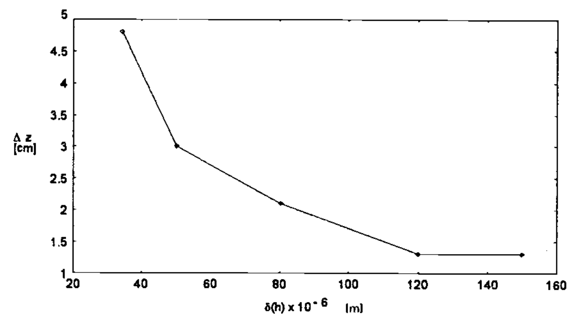

Fig. 2.) Graph of particle displacements, Δz, vs. particle sizes, δ (h).

The process was repeated with the specklegram 2. Since the fringes on this plate at some orientations have different spacings, different values of $\delta(h)$ and Δz were calculated. A graph of Δz (the distribution of the displacement of the particles) was plotted against $\delta(h)$ (the statistical probability distribution of the particles sizes) as shown at figure 2. The first point on the graph shows the measurement made on the specklegram 1 whilst the other four points were measurements made on specklegram 2. The curve on the graph shows the various sizes of the particle in the bulk sample in relation with the distances these particles moved from the surface of the membrane of the loud speaker. The mean size of the particles was between 50μm and 150μm.

CONCLUSION

We have used speckle phenomena to determine the particle sizes of the powdery sample by double-exposure speckle pattern recording. The measurement was based on the distribution of the random displacement of the particles in the bulk sample after their interaction with the speckle field on the specklegram and the subsequent decoding of the speckle pattern on it. This technique that made use of objective speckle patterns could be extended to unaccesible situations such as sizing of on line cement particles and saw dust in wood sawmills not excluding operations in vacuum systems.

ACKNOWLEDGEMENT

The authors wish to thank Prof. G. Denardo, Office of External Activities of International Centre for Theoretical Physics (ICTP), Trieste, Italy for supporting this work and LAFOC, an ICTP affiliated centre. Also, we wish to thank Dr. M. Berta, IP, Slovakia Academy of Sciences, for his assistance and fruitful suggestions.

REFERENCES

(1.) C. M. Vest., Holographic Interferometry, John Wiley and Sons ,New York 1979, Chapter 7.
(2.) L. Celaya, J. M. Jonathan and S. Mallick, Opt. Comm. **18** (3) 1976, pg. 496-498.
(3.) P. K. Buah-Bassuah, F. Francini and G. Molesini, Am.J.Phys. **57** (4) 1989, pg. 366-370.
(4.) F. P. Chiang, Kuen-Chang Chin and Wei-Buo Chang, Appl. Opt. **20** (7) 1981, pg. 1123-1124.
(5.) E. S. Wu and D. B. Geohegan, Am.J.Phys. **51** (4) 1983, pg. 315-320.
(6.) J. C. Dainty, Laser Speckle and Related Phenomena, Spring-Verlag, Berlin 1984.
(7.) R. K. Erf, Speckle Metrology, Academic Press, New York, 1978.
(8.) E. Hecht and A. Zajac, Optics, Addison-Wesley, Reading, MA, 1974.