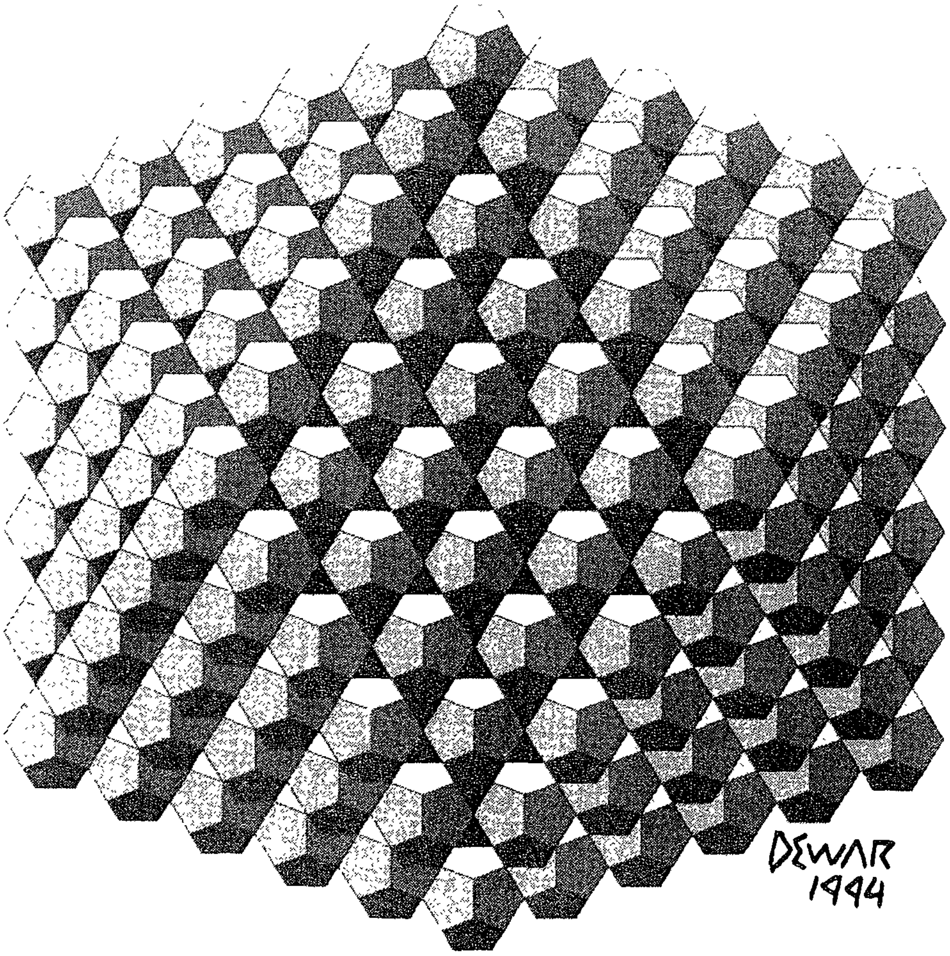
Symmetry: Culture and Science

Symmetry: Natural and Artificial, 2

The Quarterly of the
International Society for the
Interdisciplinary Study of Symmetry
(ISIS-Symmetry)

Editors:
György Darvas and Dénes Nagy

Volume 6, Number 2, 1995



Third Interdisciplinary Symmetry Congress and Exhibition
Washington, D.C., U.S.A. August 14 - 20, 1995

DISPLACEMENT VECTOR DETERMINATION THROUGH USE of FRINGE PATTERNS SYMMETRY PROPERTIES PRODUCED BY HOLOGRAPHIC INTERFEROMETRY

Konstantin Frolov, Nina Cherpakova and Geronti Sakhvadze;
Mechanical Engineering Research Institute of Russian
Academy of Sciences, 101830,Moscow, Griboedov Str.,4,Russia

In the field of experimental mechanics the analysis of the fringe patterns symmetry properties produced by holographic interferometry provides to get information on the displacement components vector relation: the component normal to the surface under examination and the component that is in the plane of this surface.

The measurement of the displacement distribution well-known holographic interferometry method is applied [1]. For this purpose two holograms of the rough surfase in its undeformed and deformed states are superimposed on the same photoplate, the interference pattern characterises the displacement initiated between two exposures. In the case of flat surface the image-plane technigues can be used, where surface image is located close to the hologram by means of objective. Application of image-plane holography provides data of displacement vector in discrete points of the surface using technique of the optical filtering [2]. This procedure cousists of scanning of hologram by narrow laser beam and the following analysis of the produced fringe picture.

Real images of small parts of the surface (in board of small viewing aperture) in their primary and moved positions play role of two point sourses displaced in space.

It`s known the interference patterns of two point sourses are presented by the second order curves, and quantative analysis of which is rather difficult. It is possible to show that under condition of small aperture of applied objective these curves may by approximate as sections of circles radius of which is defined by normal component, and displacement of the centre can be calculated by the relation between tangential and normal components.

Consider particular cases where only one component presents in the three-dimensional displacement vector: Tangential displacement U results in well-known type of straingth interference fringes analogous to the classical Young`s fringes. The fringes width (a) defines the value of displacement according the relation : U = λR/a, where λ - laser wave length (λ = 0.63 μm for He-Ne laser) and R - distance between hologram and flat screen. The direction of fringes is perpendicular to the direction of displacement. Example of this picture for given U = 10 μm in horizontal direction is presented at the fig.1. Symmetry of these pictures depends on phase propeties of interference beams (object and reference), defined by the geometry of experimental setup and displacement value.

The component W normal to the surface results in producing of fringe pattern in a view of concentric circles like Newton`s ringes. Radius of such ringes is defined according to expression: $r = R\ 2(1-N\lambda/W)$, where N - absolute number of the fringe. It is more convinient to present N as $N = N_{max} - m$, where N_{max} - maximal order in the centre of picture symmetry. By measuring radius of fringe r_m with the number using the expression: $W = 2R^2m\lambda/r_m^2$, it is possible to calculate value of normal displacement. The example of this picture corresponding to W = 2000 µm is given at fig.2.

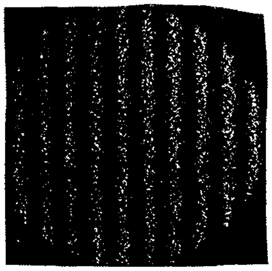


Fig.1 - Interference pattern for in-place displacement

In common case when displacement vector containes both normal and tangential components results in appearing of interference fringes as plots of ellips, parabolas and giperbolas. Under condition $r \ll R$, where r - aperture radius of observation field their approximation is possible to present as plots of circles. The centre of these circles doesn`t coincide with the centre of field aperture. As a result the pictures become asymmetric.

The normal component using the previous formula can be defined. Asymetry of measured as a displasement of the circle centre relatively to the centre of observation field is defined by relationship between normal and tangentional components: p = UR/W. In particular cases when tangentional component U equal to zero (U=0), than displacement p = 0 and the picture becomes symmetrical; when normal component w = 0 radius of circles aspires to infinity and fringes look like straight Young`s fringes.

Recieved equations were used for analysis of interference pattern and determination of the displacement vector contained both normal and tangentional components. This pattern for given W = 1500 µm and U = 24 µm is shown at fig.3. The displacement determination error didn`t exceeded 3 %.

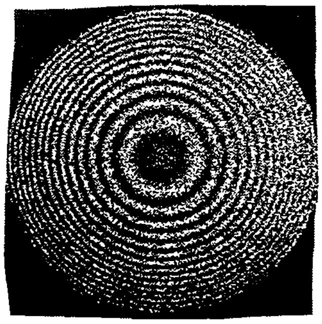


Fig.2.-Interference pattern for normal displacement

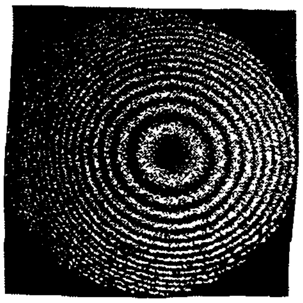


Fig.3.- Common case of three-dimensional displacement

From the point of view of the measurement precision the worst case has place when both components have the same order of magnitudes. It results in asymmetrical pictures, centre of which is lokated out of the observation field. Special procedures must be applied for their analysis. Under these conditions the measurement error increases till to 10-15 % .

References

1. Vest C.M.Holographic Interferometry. New York, 1979. 504 p.

2. Boone P.M., De Backer L.C. Determination of Three-ortogonal Components From One Double Exposure Hologram. Optics, 1973, v.37, p.61-81.