Moiré interferometry – Technique and Application

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Összefoglalás

Moiré interferometria – Technika és alkalmazás. Szerzők röviden összefoglalják a moiré interferometria alapját képező optikai interferenciakép keletkezésnek elvét (1. ábra), leírják a virtuális referenciarács jellemzőit [2. és 3. ábra, és (1) – (7) egyenletek], bemutatják a vizsgálati technikát: a segéd-rácsetelon felvitelét (4. ábra) és a moiré interferométer felépítését (5. ábra), majd két példával (6. és 7. ábra) szemléltetik a próbatest felületére felvitt segéd-etalonrács mint valós diffrakciós rács és a kétirányú lézerfény megvilágítással létesített virtuális referencia rács között létrejövő optikai interferenciakép méréstechnikai alkalmazását.

Introduction

Moiré interferometry is a powerful in-plane displacement measurement tool for mechanical strain analysis. It is high sensitive and applicable to many research and engineering fields (see the references [1] – [3]). The difference between geometric moiré and moiré interferometry is schematically shown in *Fig. 1.* In the geometric moiré method two real gratings (specimen- and reference-grating) interacts. The moiré fringe pattern appears as a result of geometrical superposition.

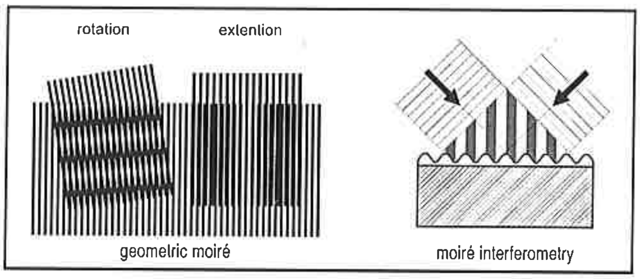

Fig. 1. Basic set-up of geometric moiré and moiré interferometry
1. ábra. A geometriai moiré (elfordulással, elmozdulással) és a moiré interferometria létrejöttének elve

Moiré interferometry means, the fringe pattern appears as a result of optical interference. That is, a real existing diffraction grating on the surface of a specimen interacts with a virtual reference grating and forms moiré pattern. The reference grating is generated by two crossed light wave trains (see Fig. 1, right side). The relationship between the fringe orders and in-plane displacement components is the same as in geometric moiré, namely

$$u_x = \frac{1}{f}\cdot m \qquad and \qquad u_y = \frac{1}{f}\cdot n \tag{1}$$

where f is the frequency of the virtual reference grating.

Mathematical analysis

The generation of the virtual reference grating is shown in *Fig. 2.* Two light wave trains with the field strengths

$$A_1 = a_1\cos 2\pi\omega t \qquad and \qquad A_2 = a_2\cos 2\pi\left(\omega t+\frac{\delta}{\lambda}\right) \tag{2}$$

generate in their cross zone the new harmonic wave

$$A = A_1 + A_2 = \tilde{a}\cos 2\pi\left(\omega t+\phi\right) \tag{3}$$

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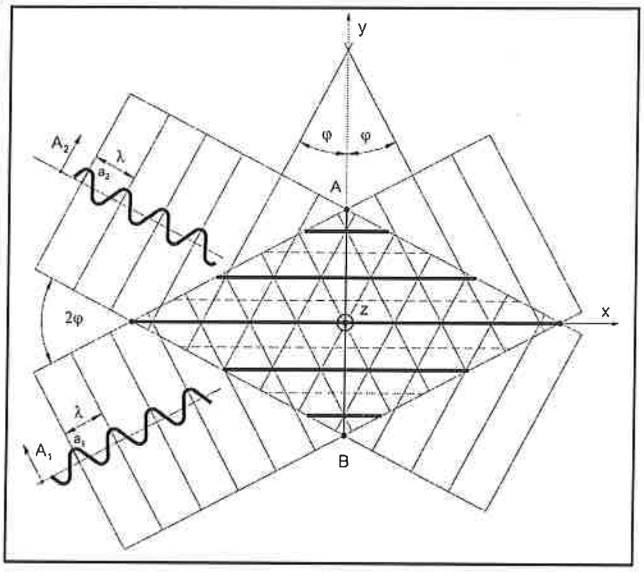

Fig. 2. Generation of a virtual reference grating between A and B
2. ábra. Virtuális rács létrehozása az A és B pontok között

with the amplitude

$$\tilde{a} = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos 2\pi\frac{\delta}{\lambda}} \tag{4}$$

and the resultant Intensity

$$I = a_1^2 + a_2^2 + 2a_1a_2\cos 2\pi\frac{\delta}{\lambda} \ . \tag{5}$$

Assumed the waves have the same peak strength follows

$$I = 4a^2\cos^2\pi\frac{\delta}{\lambda} \ . \tag{6}$$

That implies in the cross-zone between the points A and B the intensity distribution according to *Fig. 3.* with the frequency

$$f = \frac{2\sin\alpha}{\lambda} \ . \tag{7}$$

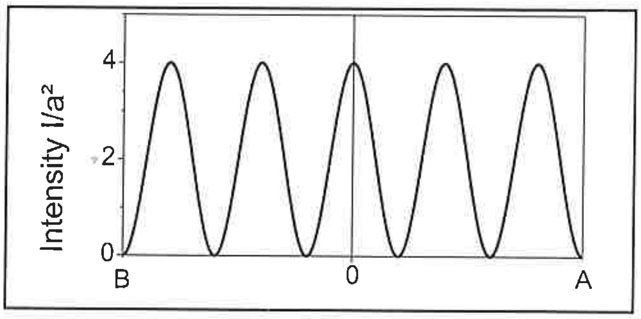

Fig. 3. Intensity distribution between A and B (Fig. 2)
3. ábra. Intenzitás-eloszlás a 2. ábra szerinti A és B pont között

As an instance we use laser light with a wavelength λ = 532 nm and an angle of incidence φ = 48.15°. The frequency of virtual grating results in this case to f = 2800 mm^{-1}.

Grating replication and optical systems

One important condition for the realisation of moiré interferometry is the preparation of a high quality specimen grating with 1000-2000 lines/mm. The next figure shows steps in producing this grating by a replication process. Starting point is a high precision submaster grating with a detachable line ore crossline structure in form of a metallic film, prepared on the surface of glass plate. This submaster grating is provided by [4]. In the replication process (*Fig. 4*) the metallic film is transferred from an original photoresist or submaster grating to the specimen.

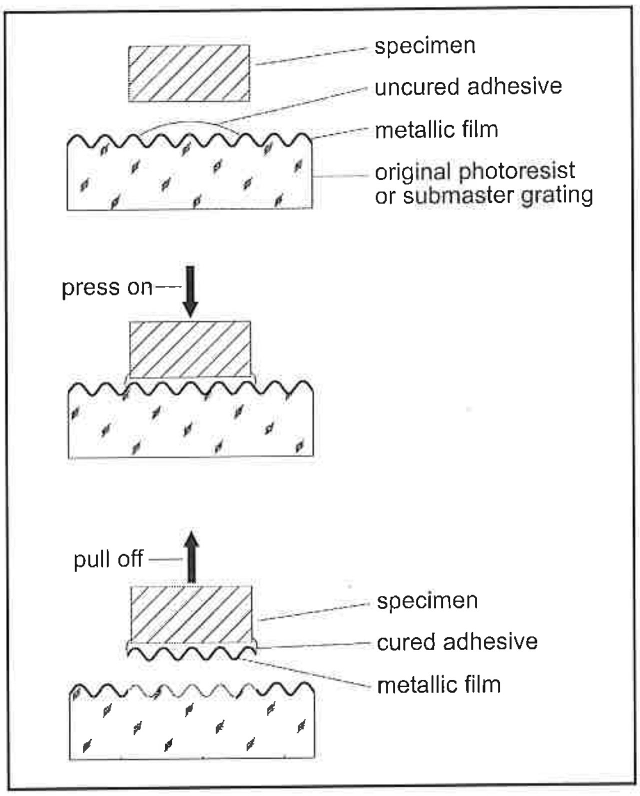

Fig. 4. Replication of specimen grating
4. ábra. A segéd-rácsetalon felvitele a próbatest felületére

A typical moiré interferometer system with reflection grating as beam splitter is shown in *figure 5*. The specimen with specimen grating is illuminated by two parallel laser beams. A CCD-camera records the moiré fringe pattern. The complete system must be isolated to vibrations.

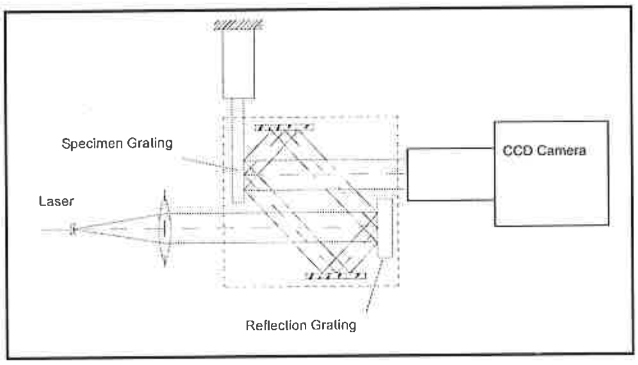

Fig. 5. Moiré interferometer
5. ábra. A moiré interferométer felépítésének vázlata

Applications

The moiré interferometry is used in various fields. The following figures show two examples of their application at the Chemnitz University of Technology.

First example is the determination of residual stress (*Fig. 6*). A ring of epoxy resin is shrinked onto an aluminium disk. Comparable with the strain gage hole-drilling method are measured the displacement fields around the hole resulting from the drilling process.

The particular steps are:
1 replicate the specimen grid on the disc with residual stresses
2 drill the hole
3 measure the displacement field's u_x, u_y
4 calculate the deformation state
5 calculate the residual stress state

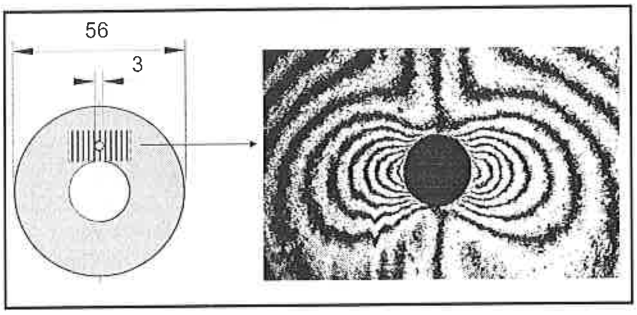

Fig. 6. Residual stress measurement, hole drilling method
6. ábra. A visszamaradó feszültségek mérése az alumíniumtárcsára zsugorított epoxigyanta gyűrűben a lyukfúrásos módszerrel

The second example is the measurement of the strain transmission from the specimen surface to the metallic foil of original strain gages (*Fig. 7*). The aim of this investigation is the design of strain gages with defined properties in relation to their sensitivity in longitudinal and transversal direction. More details about the experiments and numerical simulations are described in [5].

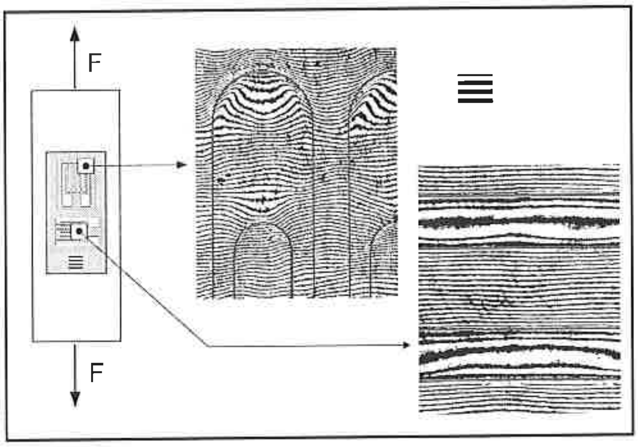

Fig. 7. Measurement of the strain transmission in original strain gages
7. ábra. A nyúlásátvitel mérése a próbatest és a felületén rögzített nyúlásmérő bélyeg között

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