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X-ray residual stress measurement

1. Introduction

In this experiment, the basics of X-ray residual stress measurement will be developed and the possibilities and limitations of this measurement method discussed the example of a surface-hardened sample.

2 Basics

2.1 The term "residual stresses"

Under residual stress is generally understood stresses in a component to which act no external mechanical stresses, and the one constant in time and space temperature field subject. The costs associated with the residual stresses internal forces and torques in mechanical Balance.

Depending on their scope residual stresses in such a 1st, 2nd and 3rd species be divided into:
· Stresses 3rd species (micro-inhomogeneous residual stresses) are microscopic in nature. To change the amount and / or direction within a grain. They are formed of a dislocation near a lattice defect, for example.
· Stresses the second type (homogeneous microstructure residual stresses) are constant inside a grain, but vary from grain to grain. They are a result of Streckgrenzenanisotropie, ie, the yield point of different phases in the material is different, thereby occurs a plastic deformation inhomogeneous. Reason for these residual stresses can be different thermal expansion coefficients of different phases in multiphase material
· Residual stresses 1. Type (macro residual stresses) extend over macroscopic areas of a workpiece, that is, over several grains. Residual stresses 1st kind arise, for example during forming, mechanical machining or during the heat treatment of metallic materials.

Figure 1 shows the schematic course of the voltages along a cutout structure with the corresponding definition of the residual stresses 1st, 2nd and 3rd type.

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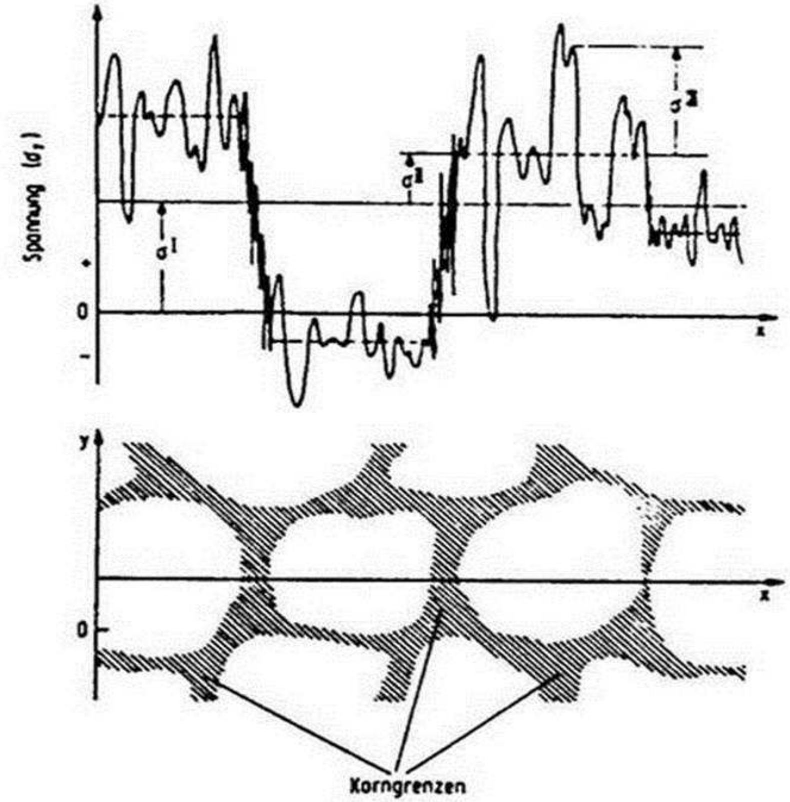

Figure 1: Schematic of the internal stresses along the surface
a structural detail of a metal sample

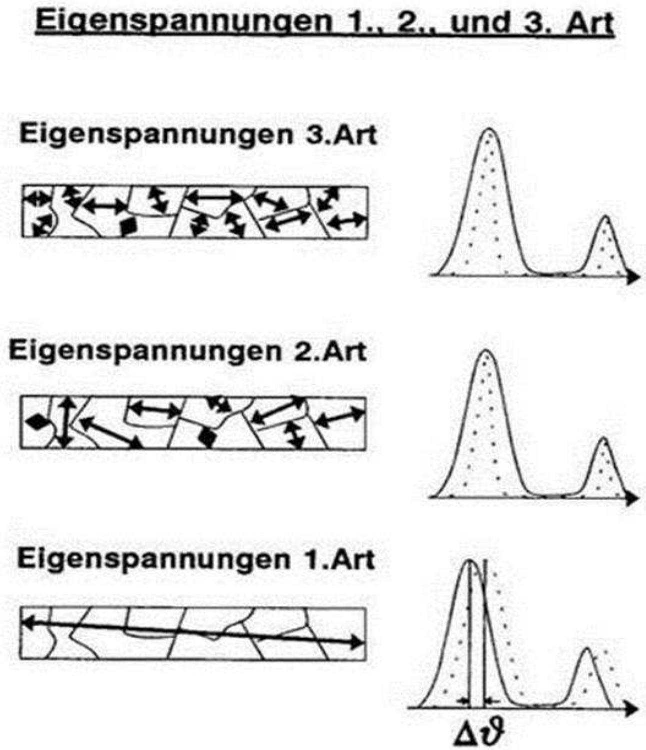

Figure 2: Effect of residual stresses 1st, 2nd and 3rd type
at the peak of an X-ray diffraction

Since a plurality of grains are detected by the X-ray in X-ray diffraction pattern of polycrystalline materials in general, residual stresses are 2 and 3. FIG. Art indistinguishable and superimposed on the residual stresses 1. Art. due to a higher spread of lattice spacings they lead to a broadening of the Peaks. Residual stresses 1st kind, however, cause a shift of the peak maxima to DJ, since all the reflecting lattice planes of a lattice planes in the same , Be distorted. This is illustrated in Figure 2

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2.2 Measurement of residual stresses (sin2y method)

For the experimental determination of residual stresses are a wide variety of destructive and nondestructive measurement methods. The most important destructive method represent the radiographic measurement procedures. Part of this group also under the experiment presented sin2y-Method.

Stresses first type lead to elastic distortion of the unit cell. the interplanar spacing varies according to a result of a force acting on grid power from D0 D, this leads to a change in the position of the interference line, as Figure 3 show

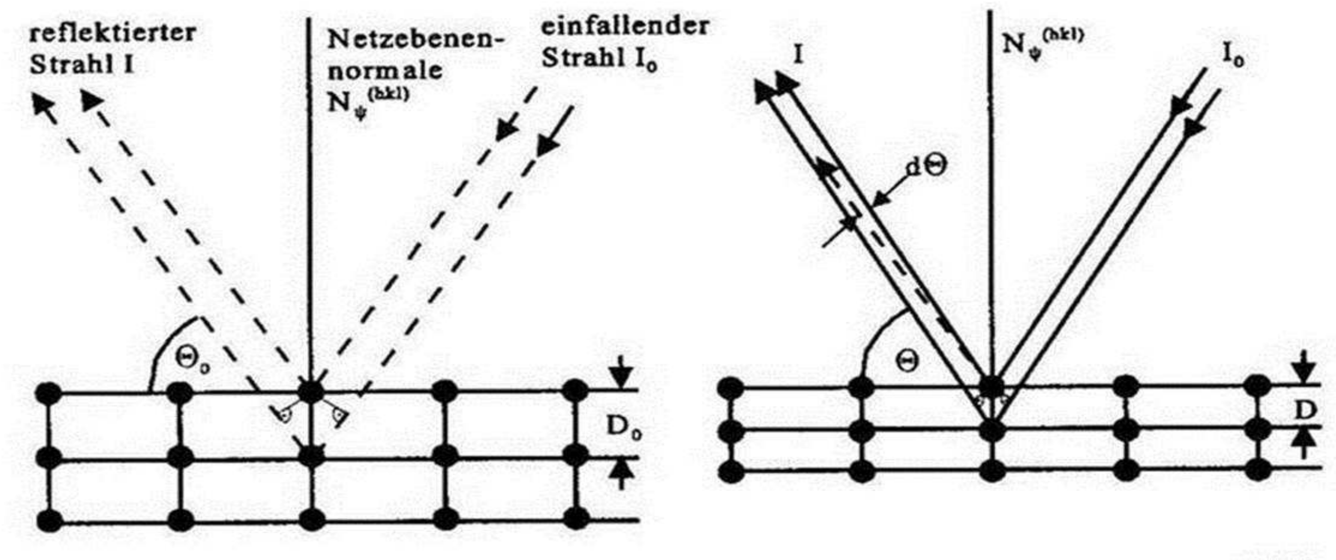

Figure 3: Bragg reflection at a stress-free (left) and a strained lattice (right)

Since the penetration depth of X-rays is low (approximately 10-20 microns, depending on material and radiation used), only areas near the surface of the sample detected. A possibly available z component of the stress is on the surface of the absence of restraint is always zero. That is, to measure with the proviso that in the captured sample volume no z-voltage component is present, a two-axis (plane) state of stress in the Sample surface.

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Figure 4 illustrates the recording technique in X-ray stress measurement. While in the Diffraktometeraufnahme in a conventional beam geometry only Lattice planes come to the reflection, which are parallel to the sample surface, is achieved by tilting of the specimen by the angle y that, in the voltage measurement also reflect such power levels, which are not oriented parallel to the surface.

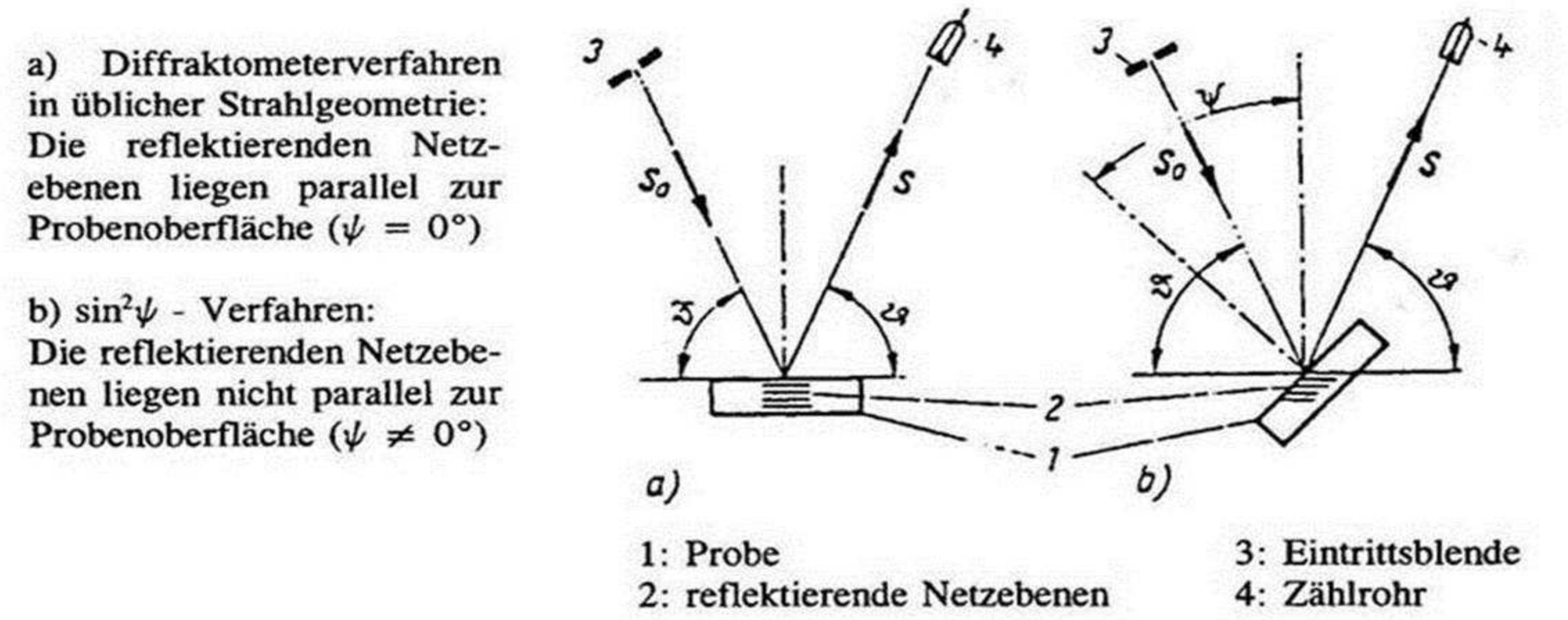

Figure 4: recording technique in the X-ray voltage measurement

In the investigation of polycrystalline materials multiple crystallites are detected by the primary beam. If one measures a sample y in different directions, so obtains the intensity of lattice planes of different orientation, different when a voltage is interplanar spacings

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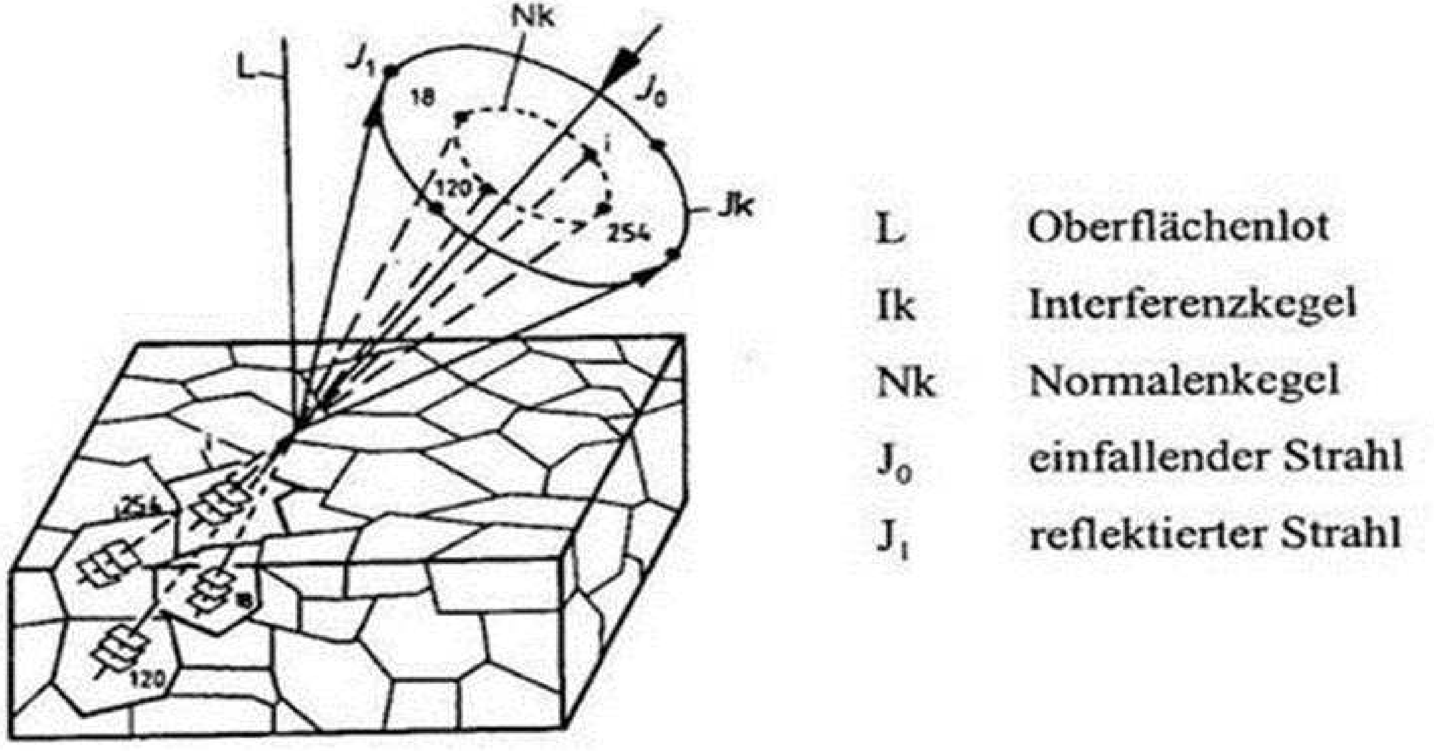

Figure 5: formation of the interference cone in many crystalline materials

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For determining the tension in the solid state, the combination of the measured lattice stretching with elasticity theoretical point is necessary.

the coordinate system shown in Figure 6 with the angles y j and sets it as a basis, is the relationship between the measured strain e j, y and surface-parallel main voltages S1 and S2 and the main strains e1, e2 and e3:

$$\varepsilon_{\varphi,\psi} = \varepsilon_1 \cos^2 \varphi \sin^2 \psi + \varepsilon_2 \sin^2 \varphi \sin^2 \psi + \varepsilon_3 \cos^2 \psi$$

Linking the main strains of the principal stresses is given by Hooke's law:

$$\varepsilon_1 = \frac{1}{E}(\sigma_1 - \sigma_2) \qquad \varepsilon_2 = \frac{1}{E}(\sigma_2 - \nu\sigma_1) \qquad \varepsilon_3 = -\frac{\nu}{E}(\sigma_1 + \sigma_2)$$

Thus, Equation 1 can be written as

$$\varepsilon_{\varphi,\psi} = \frac{\nu + 1}{E}(\sigma_1 \cos^2 \varphi + \sigma_2 \sin^2 \varphi) \sin^2 \psi - \frac{\nu}{E}(\sigma_1 + \sigma_2)$$

The introduction of Voigt's elastic constants

$$\frac{1}{2} S_2 = \frac{\nu + 1}{E} \qquad S_1 = -\frac{\nu}{E}$$

Yields the fundamental equation of the X-ray method for determining elastic stresses in its most common presentation:

$$\boxed{\varepsilon_{\varphi,\psi} = \frac{1}{2} S_2 \cdot \sigma_\varphi \sin^2 \psi + S_1(\sigma_1 + \sigma_2)}$$

With

$$\sigma_\varphi = \sigma_1 \cdot \cos^2 \varphi + \sigma_2 \sin^2 \varphi$$

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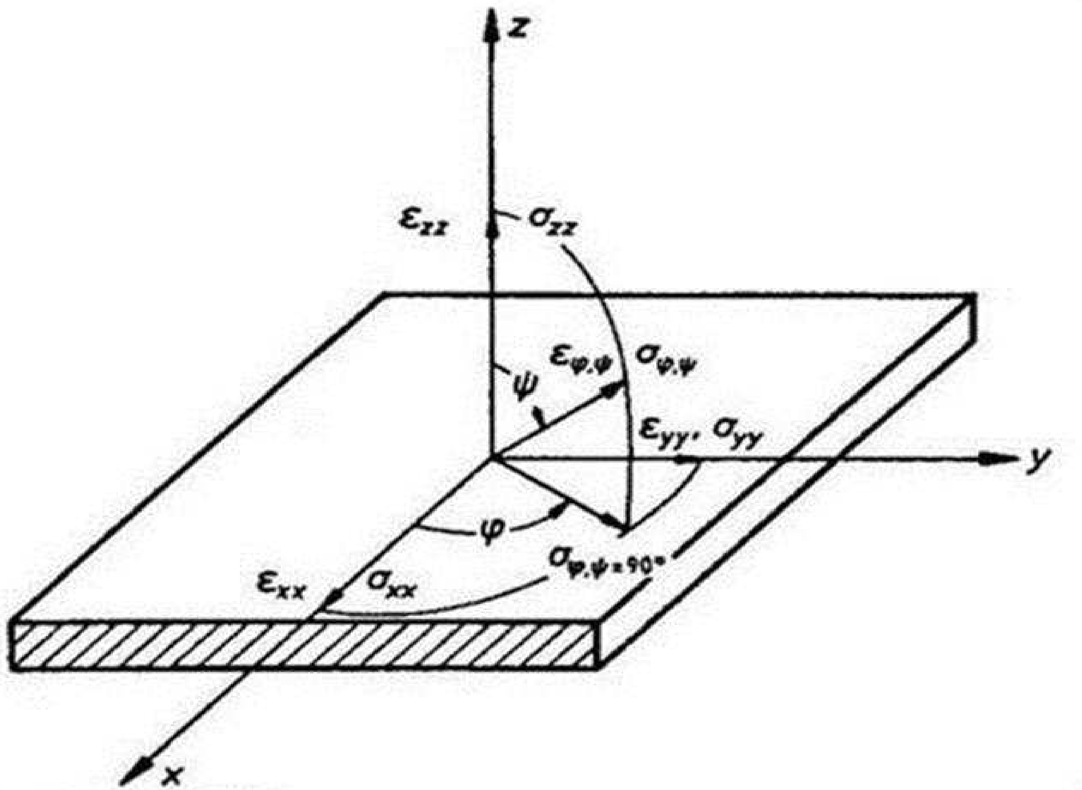

Figure 6: Definition of the coordinate system with the angles j and y

The determination of the plane stress is thus reduced to the determination of the lattice strain ej, y, which means the change of the interference fringes
can be measured lay. Equation 5 can be regarded as a linear equation. Plotting the elastic const strains for j =., As a function of sin2y o
the result is a straight line whose slope is proportional to j effective in azimuth voltage component sj and the ordinate of the sum of the
is determined principal stresses in the surface (Figure 7). For the separation of the principal stresses in the surface, it is necessary, different in at least three
to measure j directions.

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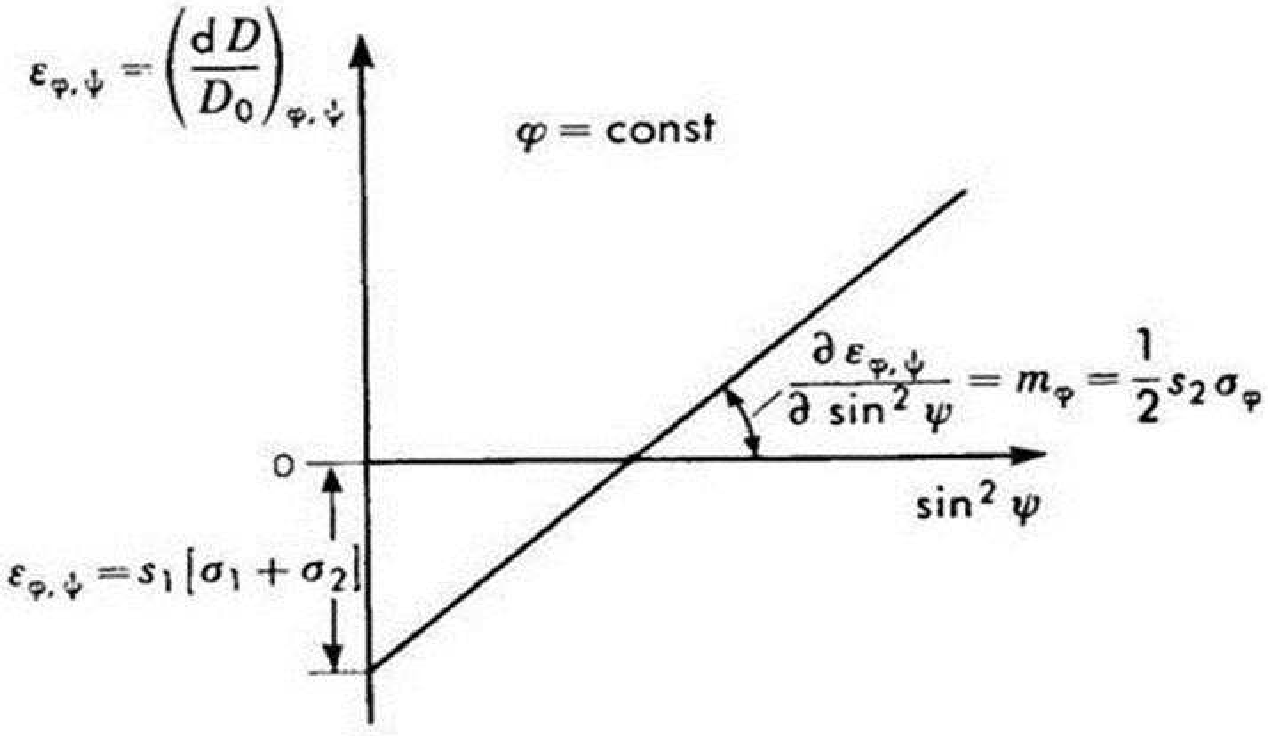

Figure 7: strain distribution in the azimuth plane j = const a planar surface parallel stress state.

3 Exercises

the voltage components parallel and perpendicular to measure X-ray to the feed direction of the laser to a laser beam cured sample.
The evaluation is performed using the sin2y plot

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