1. INTRODUCTION

The moiré methods are well-known for analysing the contour and the deformation of an object [1]. The moiré fringes do not lead only to the wanted values but represent also a qualitative overview to the nature of the deformation. However their automatic evaluation is relatively difficult by digital picture processing: First the fringes are generally of no regular structure and moreover their order cannot be determined without additional information of the related experiment. Usually the input of the order must be done interactively.

The mentioned problems can be avoided by applying a new method developed from the phase shift principle of the holographic interferometry [2]. Instead of analysing the geometric contours of the moiré fringes their grey intensity values related to three phase shifted moiré patterns in one point are used for calculation of the displacement of a deformed pattern compared with a known reference pattern. By this procedure described in detail in [3] one gets the grating displacement not only on the moiré fringes but also between them in distances of the grating pitch. Moreover generalized orders of the fringes follow by this process automatically.

The phase shift method needs only a simple picture processing algorithm. Furthermore the proportion of postprocessing is smaller than in the case of direct moiré evaluation.

In the following a modified phase shift method is applied to reflection moiré patterns as an example of the different moiré techniques.

2. PHASE SHIFT METHOD

Regarding holographic interferometry the phase shift of an actual beam against a reference one, contains the information needed for further calculation. A constant phase shift belongs to interferometric patterns similar to those of the moiré technique with corresponding difficulties concerning automatic digital picture processing. The idea of this phase shifting consists in considering the basic and two shifted positions of a reference beam. Usually the shifting amount is chosen to be the third part of the wave length \( \lambda \). In every case the reference beam is superposed on the deformed beam with the result of three phase shifted patterns. Then the grey values of the related intensity distributions are taken at the same local point, yielding the desired phase shift [4].

This procedure can be transferred to the moiré principle. In that case the wave length \( \lambda \) is replaced by the pitch \( p \) of the reference grating. The correspondence of \( \lambda \) and \( p \) is based on the model, that the intensity distribution of the grating can be approximated by a trigonometric function. Instead of shifting the reference beam now the reference grating is moved by an amount of \( \pm \frac{p}{3} \).

Then the local intensity can be described by

\[ I = I_G + I_D \cos \varphi \]  

whereby \( I_G \) means the local mean value of the measured intensity and \( I_D \) the amplitude of the cosine function with the phase angle

\[ \varphi = \frac{\nu_1}{p/2} \]  

In eq.(2) \( \nu_1 \) represents the local displacement of the deformed grating against the reference grating.

The local intensity \( I \) in eq.(1) is assumed to be measured in a moiré image without observable generating grating lines. If the grating lines are visible, a mean value \( \bar{I} \) integrated over an intervall of the pitch \( p \)

\[ \bar{I} = \frac{1}{p} \int_I \text{dx} \]  

must be calculated.

Regarding the local intensity \( I \) at the same local point with the co-ordinates \( x \) and \( y \) of the mentioned three patterns shifted by \( \pm p/3 \) respectively \( \pm 120^\circ \) leads to the equations

\[ I_0 = I_G + I_D \cos \varphi \]  

\[ I_m = I_G + I_D \cos(\varphi - 120^\circ) \]  

\[ I_p = I_G + I_D \cos(\varphi + 120^\circ) \]  

\[ I_0, I_m, \text{and } I_p \text{ are the measured local intensity values, while } I_G, I_D \text{ and } \varphi \text{ respectively related to eq.(2) the displacement } \nu_1 \text{ are to be determined by eqs.(4)-(6). Applying the addition theorems of harmonic functions it follows:} \]

\[ I_G = \frac{(I_0 + I_m + I_p)/3}{\sqrt{(2I_G - I_p - I_m)^2 + (I_m - I_p)^2/3}} \]  

\[ \nu_1 = \frac{p}{2} \arctan \left( \frac{(I_m - I_p)\sqrt{3}}{2I_G - I_m - I_p} \right) \]  

Eq.(9) leads to the local displacement \( \nu_1 \) of the deformed grating against the reference grating related to the main value.

The absolute displacement has the form

\[ v = \nu_1 + k p \]  

where \( k \) is an integer, which must be determined from the sequence of \( \nu_1 \) values, Fig. 1a. Every jump of \( \nu_1 \) from \( p \) to 0 means an increase of \( k \) by 1 and vice versa. Applying the procedure to \( \nu_1 \), the absolute displacement \( v \) in Fig. 1b is derived which now represents a continuous function.

The phase shift equation (9) is exact only if the generating functions are harmonic of the same period. On the other hand the moiré effect results from the difference in the period of the deformed and the reference grating. In [3] it is shown, that a difference of the period of about 10 % yields a phase error of only 2 %. 
