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Optimization of an Error due to Non-Perpendicularity of optical axis of Digital Microscope with the plane of Micro machine Base

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ABSTRACT : *Errors are introduced in Micro machining processes due to various types of External physical effects. One of the major effects often taken into consideration is known as Non-Perpendicularity. When we need to find offset between two or more movable attachments or tools on the machine, error may occur due to non-perpendicularity of the respective planes of tool and base and as a result we get approximated value of offset. This paper is made on the work of optimization of this error by developing a Mathematical Model so as to obtain precise results. The perpendicularity of the camera's optical axis to the surface being observed is one of the basic conditions for the validity of the measurement. Small magnitudes of camera misalignment angles, up to two or three degrees can go easily unnoticed during the initial setting of the experimental setup especially when the stand-off-distance between the camera and the surface is not small.*

Keywords *- Non-Perpendicularity, Camera Misalignment, Optimization, Stand-off-distance*

I. INTRODUCTION

The in-plane deformations and the perpendicularity of the viewing axis (i.e., the parallelism of the camera focal-plane-array with the specimen surface) are two of the basic assumptions for calculation of error. The occurrence of any out-of-plane translation or misalignment between the camera focal-plane-array and the specimen surface will lead to errors that are embedded in the measured displacements. Out-of-plane translations may occur during the loading of the specimen, while the non-perpendicularity of the camera, on the other hand, may occur during loading (due to out-of-plane rotation of the specimen) or may exist before loading of camera. Nowadays, digital image correlation (DIC), also referred to as the digital speckle correlation method (DSCM), has become one of the most widely used full-field optical methods for motion and deformation measurements. The DIC method was first introduced by Sutton et al. In the early 1980s and during the past three decades it underwent continuous modifications and significant improvements. Besides the good measurement accuracy of the DIC method, it also offers other attractive features which include; relatively simple experimental setup, simple or no specimen preparation and low requirements for the measurement environment. All of that have made the DIC method extremely popular among the experimental mechanics community, and both 2D-DIC and 3D-DIC are being increasingly used in a very wide range of applications ranging from material science to manufacturing, mechanical, biomedical and structural engineering.

II. SETUP

Fig.1 shows a schematic for a digital microscopic camera imaging a surface where the lens of camera is tilted about the x axis by an angle θ . The surface rigidly translates along the direction by a distance and for clarity the positions of the surface before and after the translation are shown separately.
Z represents the distance between the reference plane and the camera lens when they are perfectly perpendicular to each other. P is the distance between tool and the camera optical axis during only a right angle and P_{net} is the distance when camera is inclined with the axis of tool.

$$P_{net} = P + Z.\tan\theta$$

Similarly, for y axis the deflection will become ,

$$Q_{net} = Q + Z.\tan\alpha$$

Now,
We can also make an equation by using trigonometry, since the changes in in values of P, Q and z are very small, so

$$\tan\theta = d(Pnet - P)/dz$$

also,

$\tan\alpha = d(Qnet - Q)/dz$

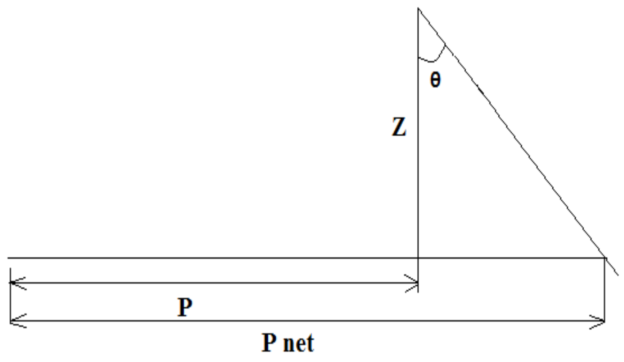

Fig. 1

III. EXPERIMENTS

In order to experimentally quantify the DIC error resulting from camera non-perpendicularity, different groups of experiments were conducted where in the first group the camera was perfectly perpendicular to the surface and in each of the other groups the camera was tilted with a different angle (from 1º to 5º in 1º steps). A schematic view of the experimental setup is shown in Fig.3. As can be seen from the figure, the camera was tilted around its own axis which is parallel to the *y* axis. In each group of experiments, while the camera is at a fixed angle with respect to the surface, the surface was translated in two steps along the *x* direction (i.e., perpendicular to the tilt axis) then in two steps along the *y* direction (i.e., parallel to the tilt axis). As a result, images were captured while the surface is at five different positions; a reference position, two translation steps in the *x* direction and two translation steps in the *y* direction. The distance between the front end of the lens and the target surface was set to about 680mm and at that working distance the field-of-view observed by the camera was about a 113mm wide. The camera was first placed close to the surface and a right-angle triangle was used to verify its perpendicularity then it was translated backwards with the aid of an optical rail to the required working distance. For each group of experiments corresponding to a different camera orientation angle, the reference position image was correlated with the images corresponding each of the two translation steps in each of the two directions.

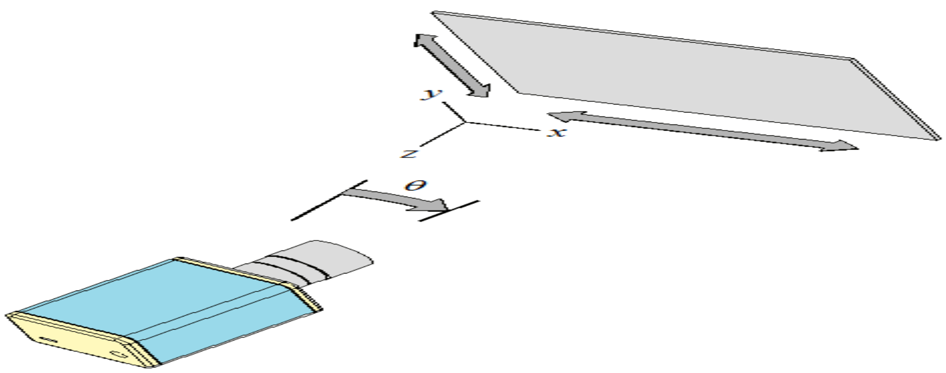

Fig. 2

IV. RESULTS

The error resulting from in-plane translation perpendicular to the tilt axis was obtained by solving above equations numerically using parameters similar to those of the experimental setup. It should be noted that some of the parameters involved in equations has very minor or no effect on the obtained. Also, other parameters were found to have very insignificant influence on the results. However, values have to be assigned to these parameters for the numerical evaluation. The values of these parameters used in the evaluation are in microns for a micro-machine. On the contrary, the tilt angle, the magnitude of in-plane-translation and the stand-off-distance have a significant influence on the resulting normal error. The influence of these three parameters was investigated by considering an appropriate range for each parameter. In the graph below, the variation of error is shown with respect to offset between camera and tool co-ordinates. Series 2 represents offset changes and series 1 represents the offset changes with respect to only camera.

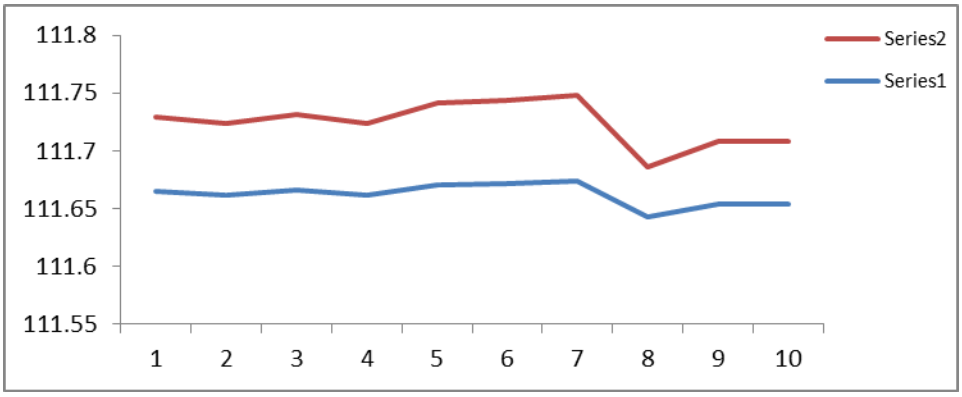

Fig.3

V. CONCLUDING REMARKS

In this work we investigated the influence of the camera's optical axis non-perpendicularity to the surface being observed on errors both theoretically and experimentally. Theoretical models were developed based on a digital microscopic camera model to estimate the errors in the measured normal and deflected values associated with in-plane translations in the directions perpendicular and parallel to the camera tilt axis. The conclusions of this investigation can be summarized in the following points.

1. When the camera's optical axis is not perpendicular to the surface being observed, any in-plane translation in the direction perpendicular or parallel to the camera tilt axis will cause errors in strain measurements.
2. In-plane translations in the direction perpendicular to the camera tilt axis cause errors in both normal components.

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