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MEASURING OF THE ABRASION OF COTYLE IMPLANT USING FOURIER PROFILOMETRY USING SEQUENTIAL DRAWING OF GRATING

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Abstract: *Contribution is focused on possibility of using Fourier profilometry for measuring of the abrasion of cotyle implant, which is caused by using in the patient's body. The projected optical structure in Fourier profilometry is sinusoidal pattern. The results showed, that sinusoidal pattern is not optimal optic structure to get sufficiently precise results. Instead of it, the linear pattern made by sequential drawing of linear strips can be used.*

Keywords: *3D measurement, Fourier profilometry, joint replacement, cotyle*

1. Introduction

3D shape measurement is today used also for measuring of abrasion of joint replacement (fig.1). These implants made of polyethylene are under stress in the patient's body and therefore they change their shape and remove some material. With measured shape of new cotyle compared with the measured shape of used cotyle, we are able to enumerate the wastage of material of implant. This abrasion is considered a key parameter of quality of cotyle implant.

Fig. 1. Polyethylene cotyle and steel femoral adapter.

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2. Methodology of measurement

2.1 Fundamentals of Fourier profilometry

One of used three dimensional optic measurement methods is Fourier profilometry [1]. This method is based on projecting sinusoidal pattern (fig. 2) on the measured object and detecting this sinusoidal pattern deformed by the shape of the object to the computer.

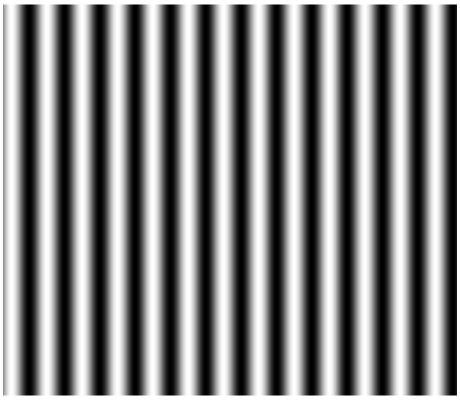

Fig. 2. Sinusoidal pattern.

Fourier transformation of the recorded sinusoidal pattern is computed. In the Fourier spectra, the carrier frequency of sinusoidal pattern is kept, others frequencies containing noise and irrelevant information are deleted. After inverse Fourier transformation, the phase from the result complex signal is obtained. Both sinusoidal patterns from the reference plain and the measured object are processed this way. After subtraction of these phases, the phase difference is obtained. The height variation [2] can be computed by.(1)

$$h(x,y) = \left[\frac{l_0 p_0 \left[\frac{\Delta\Phi(x,y)}{2\pi} \right]}{\left\{ p_0 \left[\frac{\Delta\Phi(x,y)}{2\pi} \right] - d \right\}} \right], \tag{1}$$

where *h(x, y)* is height, l_0 is the distance between the camera and the reference plain, p_0 is the period of fringe divided by *cos(θ)*, *ΔΦ* is absolute change of phase and *d* is the distance of camera and projector.

2.2 Sequential drawing of linear pattern.

The exactness of the projected sinusoidal pattern has a great influence on the result of the measurement, and its uncertainty. It is not so easy to make an exact sinusoidal pattern and to get a precise result. Another problem is, that more rugged surface changes the frequency of sinusoidal pattern a much, and it is problem to filtrate this pattern in its Fourier spectra. But it is possible to replace the sinusoidal pattern by a linear grating, and compute its “phase”. If we presume, that each line in the grating is a common point of the sinusoidal pattern, we can compute values of phase in these points. If the linear grating has sufficiently big frequency, we can interpolate points between the lines of the linear grating and obtain the whole duration of the phase.

Of course, it is necessary to assign each point of line of the linear grating the precise coordinates. Therefore we use as the line projector the laser diode with the cylindrical lens to focus the laser trace into the line (fig.3).

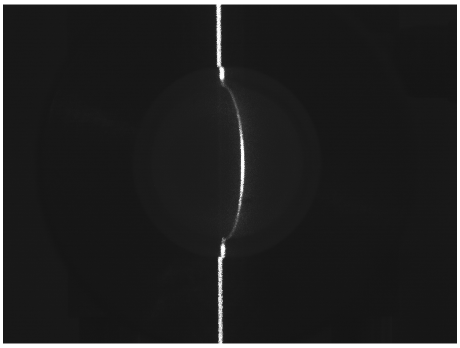

Fig. 3. Laser line projected on the cotyle.

After projecting this vertical line on the measured object and its detection into the computer, the Gauss interpolation is done in every horizontal line, so we get the precise coordinates of the middle of projected line [3]. The laser diode is placed on the position table. After scanning the line into the computer, position table is moved by the constant distance, and the another detection is done. The whole measured object is scanned this way. After the measurement is done, we have the linear grating covering whole measured object deformed by its shape, as shown on fig. 4.

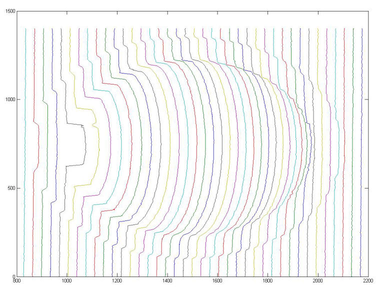

Fig. 4. Linear grating on the cotyle.

Now we can compute the common points and interpolate the phase of such grating and subtract it from the phase obtained on the reference plain. Then the height (fig 5) variation is computed by (1).

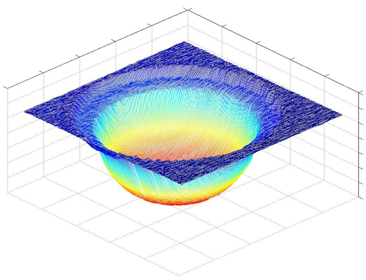

Fig. 5. Result of 3D measurement of cotyle implant.

3. Conclusion

Some types of surface are not suitable for measurement by Fourier profilometry using the sinusoidal pattern. In this case, the linear pattern can be used. On the more rugged surface using the linear grating leads to the more precise result.

Fourier profilometry using the sequential drawing of linear grating showed itself useful to measure the cotyle implant. In the future, the large file of cotyles will be measured and their wastage of material will be enumerated. From the created statistic file, the quality of the implants and their lifetime will be increased.

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