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Study For The Measurement Of Cantilever Beam Deflection By Using Digital Projection Speckle Correlation Method (DPSCM)

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Abstract. Digital Projection Speckle Correlation Method is a new technique of 3D morphology measurements based on Digital Speckle Correlation Method.In this paper,cantilever beam deflection concentrated load is measured well by DPSCM,which reflects effectiveness of the method.

Introduction

Deflection is one of complementation most significant index in projection design. Theoretical calculation and experimental measurement are always being complementary action,but the latter is more important in some cases.with development of micro-machining,as a sensor ,which is low cost,small,highly sensitive,reliable and adaptive, cantilever beam has been applied in Physics,Chemistry,Biology,and mechanical system field.This kind of sensor displays the variation of informations relying on displacement, stress, strain, bending moment and deflection of the beam, therefore the description and measurement for these Mechanics parameter are the key point of Sensors and Application[1].There are many ways to measure deflection,and every method has its advantages and shortcomings[2].According to work environment and requirement better method would be chosen.Especially,optical method is gained more and more attention.It is because of full field, loss-less, non-contact, highly sensitive, and feasibility in complex electromagnetic environment particularly.

The Digital Projection Speckle Correlation Method (DPSCM)[3] is a new measure method,comparing with traditional way ,convenience,anti-interference,and automation are considered[4-5]. In this paper,we make use of DPSCM to measure the deflection of cantilever beam which is loaded concentrated load,and experimental result coincides with theoretical value.This kind of method lay the foundation for projection.

Method

The Digital Projection Speckle Correlation Method (DPSCM):Random speckle of LCD projector made by computer is projected on the reference plane. To begin with,the object under test ought to be put on the reference plane. Because of the variation of sample surface,the location of original speckle certainly would be changed which is named speckle displacement. It is convenient to obtain the displacement by using DPSCM. The principle is shown in Fig.1

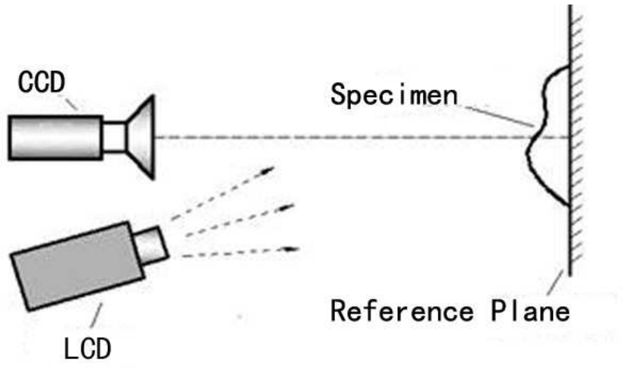

Fig.1 The principle diagram of DPSCM

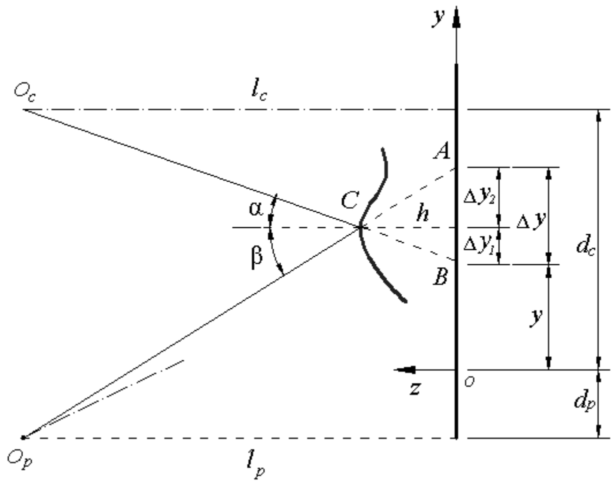

Fig.2 The schematic diagram of displacement in plane and height of sample

O_p is light source of LCD, L_p is the distance between reference plane and O_p, O_c is optical center of CCD， L_c is the distance between reference plane and O_c .In Fig.2 a beam of light is intersected on A with reference plan.After putting sample on the plan,former light will be intersected on C， because of the height h between the surface and reference plane. According to reversibility of optical path,for point C，the location of C recorded by CCD is actually B in X-Y plane，therefore AB i.e. Δy is related to the height of every point of object.And h could be gained in following formula:

$$\frac{\Delta y}{h(y)} = \frac{d_c - y}{l_c} + \frac{d_p + y + \Delta y}{l_p} = \left(\frac{d_c}{l_c} + \frac{d_p}{l_p}\right) + \left(\frac{1}{l_p} - \frac{1}{l_c}\right) y + \frac{1}{l_p} \Delta y \tag{1}$$

$$h(y) = \frac{\Delta y}{A + By + C\Delta y} \tag{2}$$

Where $A = \frac{d_c}{l_c} + \frac{d_p}{l_p}$, $B = \frac{1}{l_p} - \frac{1}{l_c}$, $C = \frac{1}{l_p}$.

Suppose $l_p = l_c \gg \Delta y$

$$h(y) = \frac{\Delta y}{A} \tag{3}$$

Displacement in plane V can be obtained by DPSCM, hence $\Delta y = Mv$, M is amplification factor of system.Formula.3 is changed into

$$h(y) = kv \quad \text{where } k = \frac{M}{A} \tag{4}$$

Experiment:

when concentrated force is loaded on the free end of cantilever beam(shown in Fig.3)，the deflection equation is：

$$\omega = \frac{Fx^2}{6EI}(3L - x) \tag{5}$$

F is concentrated force,E is Young modulus of the beam， I is moment of inertia，L is length, x is the position of the beam. Steels is chosen to be experimental material，Beam length equals to 20cm,h is depth， and b is breadth of section,which is illustrated in Table.1.

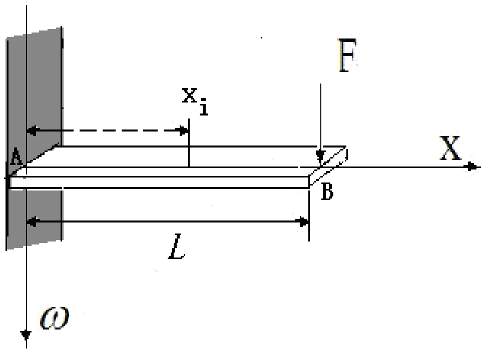

Fig.3 Schematic diagram of cantilever

Table.1 Theoretical calculation results of deflection

x_i /cm	F/N	E /GPa	h/m	b/m	ω /mm
1	9.8	200	0.002	0.01	0.072
3	9.8	200	0.002	0.01	0.628
6	9.8	200	0.002	0.01	2.381
9	9.8	200	0.002	0.01	5.060
12	9.8	200	0.002	0.01	8.467
15	9.8	200	0.002	0.01	12.403
18	9.8	200	0.002	0.01	16.669
20	9.8	200	0.002	0.01	19.600

In Fig.4,the speckle on reference plane is recorded by CCD,and saved as reference image.Loading on the beam is 9.8 Newton,and the picture is stored as target image in Fig.5.After DPSCM calculating,we have the smooth deflection chart (Fig.6),which is little discreteness and reflected full field.The experiment data and theoretical value matches well.In Fig.6,there are some error in experiment,especially near loading end,and maximum error is about 2%.This is because of parameter measurement,hence,K is higher.Besides,how to choose reference plane is also a problem.

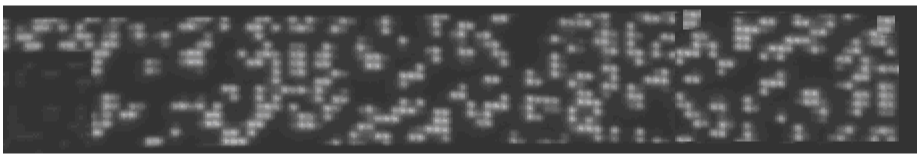

Fig.4 Reference image

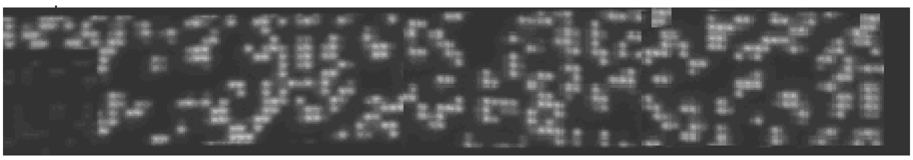

Fig.5 Target image

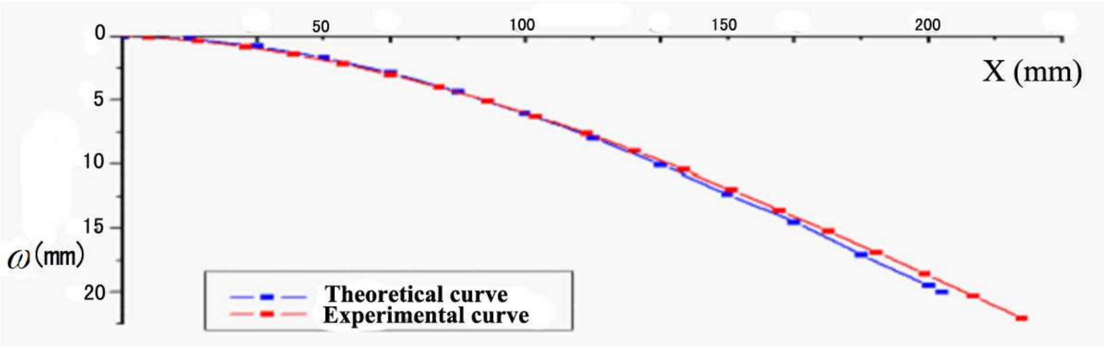

Fig.6 The graph of theoretical and experimental deflection

Conclusions

Result indicates that Digital Projection Speckle Correlation Method (DPSCM) is an accurate,full-field,non-contacted,automatic processingand convenient method for cantilever beam deflection under concentrated force.In projection ,the optical magnification could be modulated on request for different response rate.This work is the basis for further application in engineering technology.

Acknowledgements

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