研 究 速 報

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DYNAMIC MOIRE OBSERVATION BY MEANS OF STROBO-FLASH

ストロボ・フラッシュ法によるモアレ縞の動的観察

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1. Introduction

The problem of determining stress or strain caused by dynamic loading is an important subject of photomechanics. Elastic wave propagation in matter, dependent of the sonic velocity, is quite fast even when the elastic modulus is low as in case of viscoelastic material and plastics such as epoxy resin.

The time dependence of constitutive equation of viscoelastic material poses problem also from view point of photomechanics, since it may cause difference between the stress wave propagation and the strain one with time. In usual, dynamic stress distribution has been studied on the basis of photoelasticity with the aid of high speed camera or strobo-flash[1]. On the other hand, strain measuring technique by use of moire is well developed[2] and is expected available to dynamic problem.

This paper deals with an attempt to show the applicability of moire to dynamic strain measurement through the use of strobo-flash instead of high speed camera.

2. Experimental procedure and setup

This procedure is mainly based upon the use of intermittent strobo-flashing to take successive pictures of moire fringe generated by dynamic deformation of test specimen. Impact is given to the specimen by a falling weight, and the moment when the weight collides with the specimen is taken as time origin, the retarder being triggered at the moment. Electric signal is sent from the retarder to the strobo-scope after prescribed time lag, resulting in strobo-flash for the exposure of the moire. The setup used is shown schematically in Fig. 1.

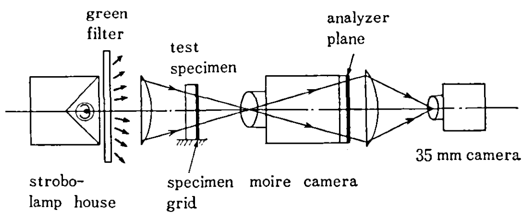

Fig. 1 Test setup

In order to compare with photoelastic analysis, epoxy resin was used as the specimen material. The sonic velocity in the resin was measured by means of ultrasonic pulse train as the ratio of the specimen length to the time required for the pulse to pass through the length, and the value is 1.67×10^6 mm/sec. This means that the relevant phenomenon in specimen of order of milimeter long should be photographed within order of microsecond.

Falling weight projected by reaction of compressed coil spring was used to impose dynamic loading. The weight is made of epoxy resin, and the impact end is covered with brass head of 10 mm in profile radius, the total weight being 8.9 g. The weight velocity can be varied up to about 8 m/sec by adjusting the compression of the spring and was calibrated by measuring the time interval for the weight to traverse two light beams

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placed at certain distance and detected by phototransistor with the aid of electronic counter.

Aluminium foil of 0. 01 mm thick and with gap of 0. 3 mm was attached as trigger on the upper edge of the specimen, and the retarder was triggered when the brass head connected the gap. Condenser and resistance were prepared in the triggering circuit to secure unique triggering even in case that the weight comes to contact with the specimen more than once after repulsion, the time constant of the circuit being taken short suitably.

In order to take clear photograph even under short exposure of strobo-flash. grill of 1, 000 lines/in (pitch: 0. 0254 mm) was printed by arc lamp on the surface of epoxy specimen by use of water soluble Fuji Photosensitive Resist No. 15, dyed by Hematin 2% solution and further blackened by potassium bichromate 10% solution.

3. Experiment and strain analysis

The strobo-flash by Xenon discharge lamp of about 5 W was so selected that the duration was 0. 8 μsec in half-width value. The experiment was carried out under the same condition of 7. 1 m/sec of the weight velocity in all the cases. The reproducibility of the experiment checked by the same photoelastic fringe in 17 photographs (semi-circular specimen, time lag: 30 μsec) shows the standard deviation of the whole setup is 0. 22 μsec satisfactorily, when converted in time.

The moire fringe generated on the analyzer plane of the moire camera was photographed on Kodak Tri X film in 35 mm camera, and the development was carried out by Fuji Pandol for 30 minutes, resulting in sensitivity equivalent to ASA 3, 200. Wave propagation in slender plate (60×15 mm), square one (60×60 mm), and hour-glass type specimen was observed by taking the photographs at an interval of 10 μsec. The shape of the hour-glass specimen is given in Fig. 2.

The moire grill was printed perpendicularly to the longitudinal axis of the specimens, and the initial moire fringe was generated by giving

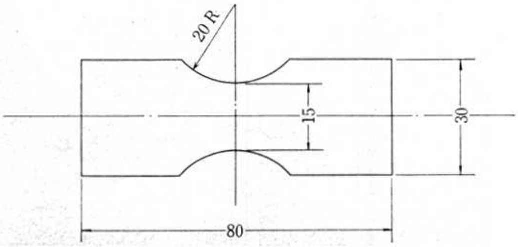

Fig. 2 Hour-glass type specimen

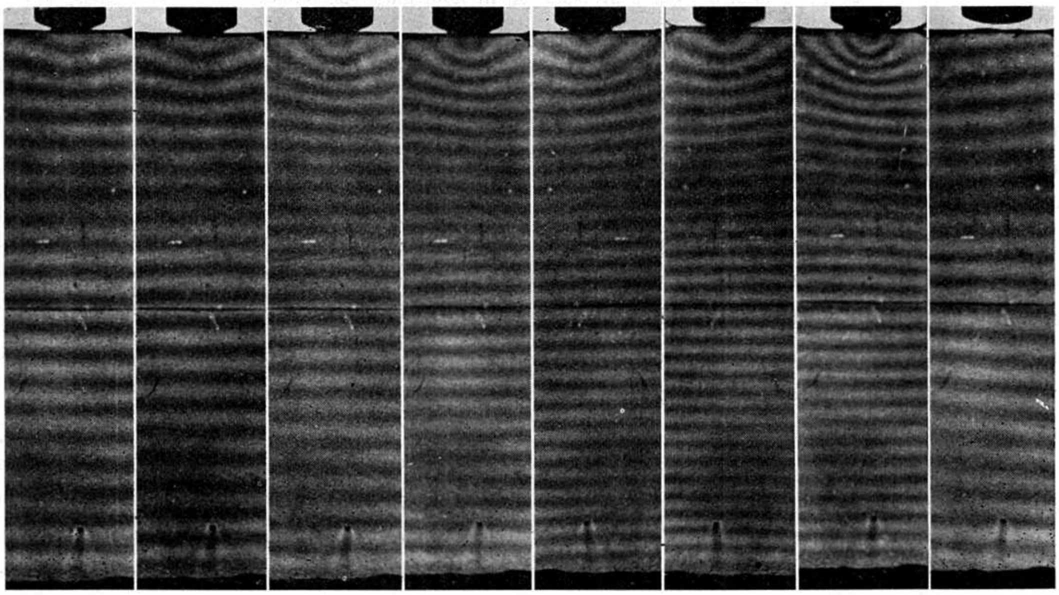

Photo. 1 Wave propagrtion in slender plate

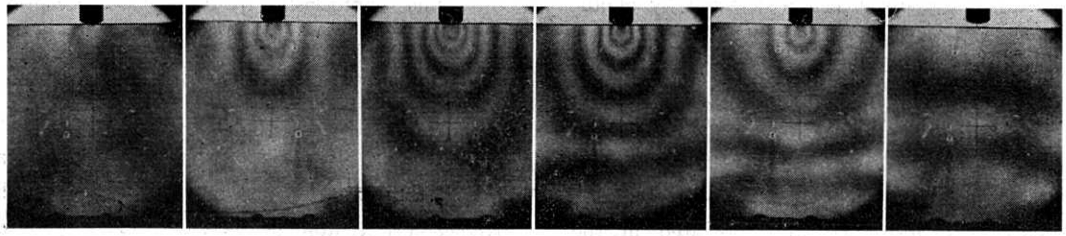

Photo. 2 Wave propagation in square plate

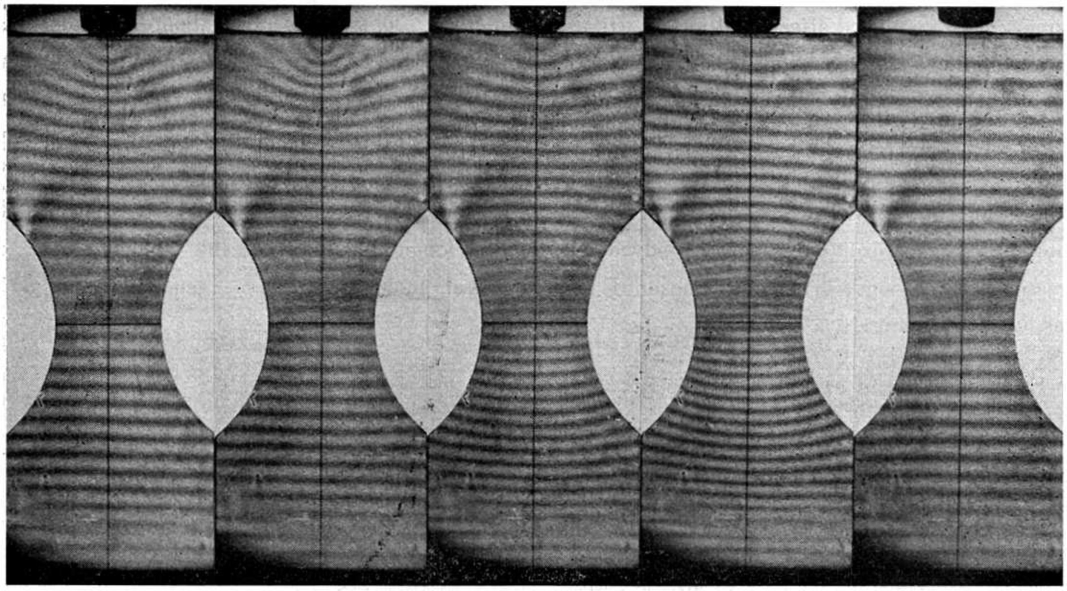

Photo. 3 Wave propagation in hour-glass specimen

mismatch. Green filter and condenser lens were inserted in the light path, in order to increase the contrast of photograph taken. The moire fringes thus obtained are given in Photos. 1 to 3. Photo. 1 shows nearly one-dimensional wave propagation in the slender plate. Two-dimensional one is presented in Photo. 2 (without mismatch), and strain concentration by fillet in Photo. 3.

These photographs enable to plot the relation between the moire fringe order and the coordinate along the central axis of the specimen, and then the normal strain concerned is calculated from the following formula[2)]

$$\varepsilon=p\left[\frac{\partial N}{\partial x}-\left(\frac{\partial N}{\partial x}\right)_{\text{initial}}\right]$$

where p is the grill pitch, N the fringe order, and x the coordinate. Fig. 3 shows the strain wave

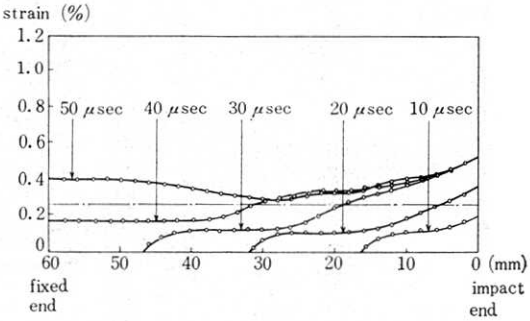

Fig. 3 Strain propagation in slender specimen

propagation thus calculated in the slender plate, including the wave reflection at the fixed end. The chain line in this figure means the dynamic strain value estimated from conventional theory of one-dimensional impact[3)]. The large strain near the impact end may be due to the strain concent-

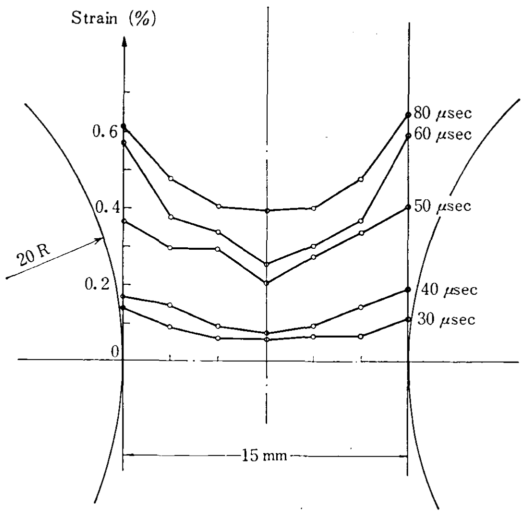

Fig. 4 Strain distribution at the root of fillt

ration by the round brass head. The same tendency appears in the case of the square plate. The strain concentration in the specimen with circular fillet is shown in Fig. 4. It is seen that the strain magnitude and distribution vary with the wave propagation.

4. Conclusions

It is made clear that the phenomenon of wave propagation can be investigated through moire by using simple setup for strobo-flashing. However, to detect precise position of the moire fringe is left to future study for the purpose of analyzing the strain value accurately. The authors wish to express sincere thanks to Prof. Yamada and Assoc. Prof. Okamura for their valuable suggestions.

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References

1) Okamura and Takano: JSME Preprint No. 154, (1966)
2) Y. Yamada: Kikai no Kenkyu, **19**, 8 (1967), 1047
3) Timoshenko and Goodier: Theory of Elasticity, 1951, McGraw-Hill

正　誤　表　(7月号)

ページ	段	行	種　別	正	誤
17	右	5	本　文	$I_x=I_x'-y_0^2A_0$	$I_x=I_x'+y_0^2A_0$
〃	〃	6	〃	$I_y=I_y-x_0^2A_0$	$I_y=I_y'+x_0^2A_0$
〃	左	12	〃	さて図4の……	さて図5の……
18	〃	11	〃	注意しなければならないことは $\|[K]\|=0$	注意しなければならないことはの逆行列
			〃	であり [K] の逆行列	

p. 17 右段の図5を下のように訂正します.