V-157 AN IMAGE ANALYSIS METHOD FOR VISUAL DATA OF FLOWING MODEL CONCRETE

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1. INTRODUCTION

The visual test which has been developed by Hashimoto[1] for two phase flow of model concrete can be used to obtain informations on deformation of aggregate phase. By using the visual test data recorded, the authors propose an image analysis method to obtain quantitative evaluation of the deformation of aggregate phase in two phase flow.

2. TESTING PROCEDURE

The apparatus used as shown in Fig.1. Instead of a circular pipe section, a rectangular pipe was selected so as to watch movement of balls away from pipe wall. Thickness of the pipe section was decided so that only one layer of balls could be accommodated inside the pipe, which enables us to observe the two-dimensional behavior of balls clearly.

Model concrete used consisted of water absorbent polymer as mortar phase and plastic balls as aggregate phase.

After placing the polymer and balls in the pipe which was kept horizontally, the piston head in the inlet pipe was moved at a constant speed while recording the movement of balls around bifurcation by a digital video camera.

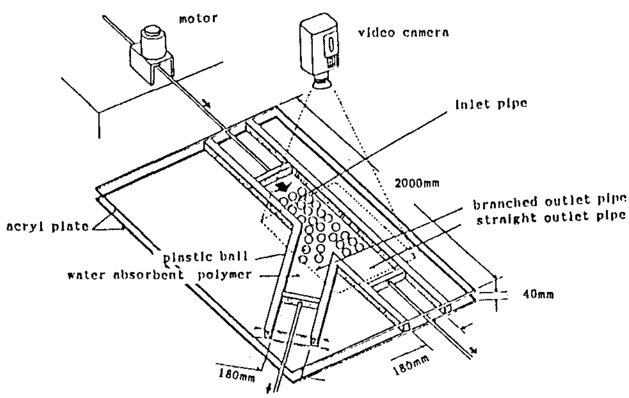

Fig.1 Apparatus of visual test

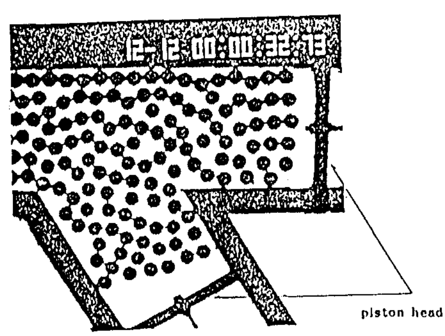

Fig.2 Recorded visual data

3. IMAGE ANALYSIS

Using the recorded video data, as shown in Fig.2, image analysis was conducted by using the A/D converter and micro processor. By using the image analyzer, the gravity center of each ball can be traced with time producing stream lines and velocity vectors of each ball.

Assuming the aggregate phase in model concrete as a continuous phase, the authors represent the global deformation field of aggregate based on Eulerian expression. Using discrete velocity data derived from each aggregate, velocity field of aggregate phase can be acquired on the assumption that velocity varies linearly between each aggregate data. Based on this assumption, velocity vector at any point can be obtained, as shown in Fig.3.

As in two-dimensional strain problem, normal co-ordinates system (x-y) is

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defined for this purpose. Normal strain ε_x in x direction and ε_y in y direction are defined in the velocity field of smoothed or "smeared" aggregate phase as follows.

$$\varepsilon_x = du/dx \quad (1)$$

$$\varepsilon_y = dv/dy \quad (2)$$

Shear strain ε_{xy} is expressed as follows.

$$\varepsilon_{xy} = (du/dy + dv/dx)/2 \quad (3)$$

Where u and v are velocity of aggregate phase in x and y directions. Normal strains ε_x and ε_y give velocity gradient of aggregate phase in x and y direction respectively. In other words, it describe variance of relative distance between aggregates in each direction. Positive ε_x means that relative distance of aggregates in x direction is increasing and vise versa. And, ε_{xy} expresses shear deformation component with constant relative distance of aggregates.

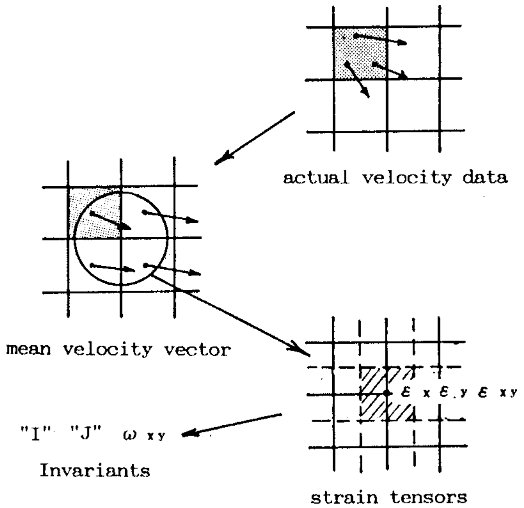

Fig.3 Procedure of deriving "I", "J" and ω_{xy}

Using above strain components, deformation rate of aggregate phase can be represented with invariants "I" and "J", independent on the co-ordinate transformation in two-dimensional tensorial expression.

$$I = (\varepsilon_x + \varepsilon_y)/2 \quad (4)$$

$$J = \sqrt{((\varepsilon_x - \varepsilon_y)/2)^2 + \varepsilon_{xy}^2} \quad (5)$$

The first invariant "I" denotes the mean deformation rate and represents the variance of mean relative distance between aggregates. Positive "I" means divergence of aggregate phase and negative "I" indicates convergence of aggregates. Assuming incompressibility in a continuum body, "I" should be zero. The second invariant "J" denotes the deviatoric deformation rate which represents the intensity of shear rate. The rotation rate ω_{xy}, peculiar to hydrodynamics, can be defined as follows.

$$\omega_{xy} = (du/dy - dv/dx)/2 \quad (6)$$

The procedure of deriving "I","J" and ω_{xy} in practice is as shown in Fig.3. Firstly, the target area on a screen is divided into finite square elements having four sides equivalent to the diameter of plastic ball. Mean velocity vector of an element can be given by computing mean value of velocity data of aggregates in the element, though vacant elements should be assigned with mean velocity of surrounding elements by means of the linear interpolation. Then "I","J" and ω_{xy} can be calculated in a point by using the strain components derived from mean velocity vector of surrounding four elements.

4. CONCLUSION

The deformation of aggregate phase can be represented by these invariants "I", "J" and a tensor ω_{xy}, provided that the aggregate phase is assumed as a continuous phase.

ACKNOWLEDGMENT

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REFERENCE

[1] HASHIMOTO,C., MARUYAMA,K. and SHIMIZU,K., Study on Visualization of Blocking of Fresh Concrete Flowing in Pipe, CONCRETE JOURNAL, Vol.26, No.2, Feb. 1988.