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COMPUTATIONAL AND EXPERIMENTAL APPROACH TO THE REDUCTION OF PRESSURE VARIATION CAUSED BY THE PASSAGE OF A HIGH-SPEED TRAIN

T. Doi*, K. Yokokawa, J. Kaku***

* Kobayasi Institute of Physical Research, 3-20-41 Higashi-Motomachi, Kokubunji, 185-0022, Tokyo, Japan

** Gakushuin University, 1-5-1 Mejiro, Toshima-ku, 171-8588, Tokyo, Japan

Tel.: +81-42-321-2841 / Fax: +81-42-322-4698 / Email: doi@kobayasi-riken.or.jp

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ABSTRACT
A pressure field around the nose part of a high-speed running train causes a pressure variation along the railway truck. In order to examine the relationship between the pressure field and the non-axisymmetric nose configuration of a train, we adopted two methods, i.e. numerical calculation and scale model experiment. Though those methods were very simple, both results agreed well and could show distinguishing characteristics indicated by a non-axisymmetric train model. From the results, we judged that the simple computational method used here would be useful in designing non-axisymmetrical nose configurations to reduce the pressure variations.

1 - INTRODUCTION
A sudden change of air stream around the nose part of a high-speed running train causes positive pressure at the tip of the nose and negative pressure at the shoulder part of the body. Such pressure distribution is called as "pressure field" and brings pressure variation at an observation point on the ground. Because the pressure variation depends on the nose configuration as well as the speed of train, the optimum design of the train body is effective to minimize it. The relationship between nose configuration and pressure field around a high-speed running train has been investigated by Howe [1], Kikuchi et al. [2], and Ogawa et al. [3] by mean of numerical calculation. The nose configurations they dealt with were conic, elliptic, parabolic, and so on. Because all of these configurations are axisymmetrical shape, it is difficult to apply the results directly to the actual trains whose nose configurations are non-axisymmetric shape. Therefore, it is necessary to confirm the difference of pressure field between axisymmetrical model and non-axisymmetric model. In this research, we calculated the pressure field around a non-axisymmetric train nose using a simple technique called the panel method. We also carried out a scale-model experiment and investigated the above subject using the both results.

2 - NUMERICAL CALCULATIONS
As is generally known, when a flow source is placed in a uniform flow, a boundary layer comes into existence between the uniform flow and the flow sprang out from the flow source. Then the air stream adjacent to the boundary layer can be regarded as the same air stream that will be formed when an object, whose shape is the same as the boundary layer, is placed in the uniform flow. If we distribute multiple flow sources three-dimensionally, by changing the positions and the strength of the flow sources appropriately, we can realize the air stream around the body of any actual train models (see Fig. 1).
When a flow sources of strength m_i is placed at coordinates (x_i, y_i, z_i) in a uniform flow of velocity u (m/s), the velocity potential at any point (x, y, z) from a total of N flow sources is given by Eq. 1:

$$\phi = u \times x - \sum_{i=1}^{N} \frac{m_i}{\sqrt{(x-x_i)^2 + (y-y_i)^2 + (z-z_i)^2}} \tag{1}$$

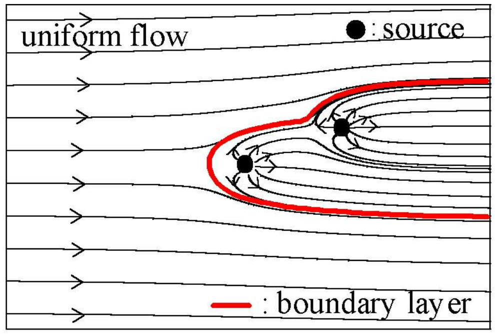

Figure 1: A fluid dynamic model with two flow sources existing in a uniform flow.

and then the flow velocity at the point is given by Eq. 2:

$$\nu = \sqrt{\nu_x^2 + \nu_y^2 + \nu_z^2} = \sqrt{\left(\frac{\partial \phi}{\partial x}\right)^2 + \left(\frac{\partial \phi}{\partial y}\right)^2 + \left(\frac{\partial \phi}{\partial z}\right)^2} \tag{2}$$

From Bernoulli's theorem, which relates the pressure and the flow velocity of a fluid, the pressure, p, is obtained as shown in Eq. 3:

$$p = \frac{1}{2}\rho\left(u^2 - \nu^2\right) \tag{3}$$

where ρ is density of the air.
Figure 2 shows an example of nose configuration of a three-dimensional train model, and Fig. 3 shows a result of the calculations for the pressure field around the nose of a train model. The size and the velocity of the train model are consistent with those of the scale model experiment. The result shown in Fig. 3 demonstrates that the pressure field is non-axisymmetric.

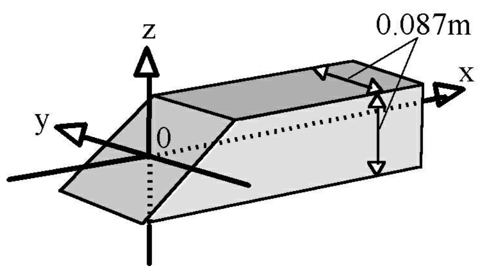

Figure 2: A train model and the coordinates.

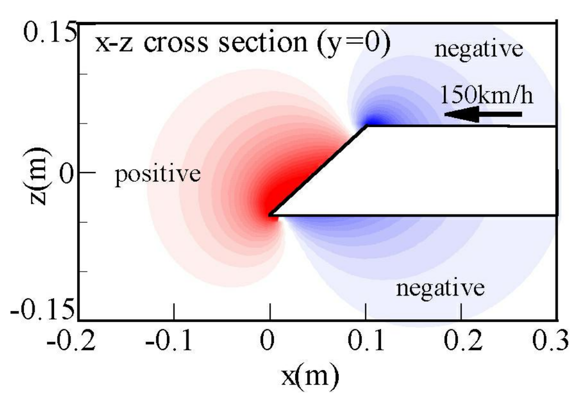

Figure 3: A result of the numerical calculation for a pressure field.

3 - MODEL EXPERIMENT

Scale model experiments were conducted to obtain the data to be compared with the results of the numerical calculation. The experimental conditions, such as the nose configuration, the size, and the train speed were almost the same as for the computation. The experimental device, as shown in Fig. 4, consisted of a compressed air tank, an electromagnetic valve, an accelerating tube, a running area (measuring area), and a braking area. The train model was ejected from the acceleration tube by the sudden opening of the electromagnetic valve and was guided to the measuring area whose length was about 4 m, and was finally stopped in the braking area. The scale ratio of the model to actual trains was approximately 1:30. The pressure field of a specific section was measured by use of arrayed low-frequency microphones set at right angles to x-axis. The speed of the train model was detected by two optical sensors located near the microphones.

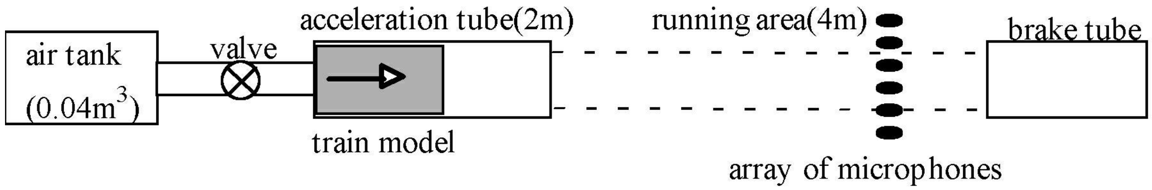

Figure 4: Schematic view of scale model experiment.

4 - RESULTS AND DISCUSSIONS

Figure 5 shows the pressure fields in a specific section obtained by numerical calculation (a) and scale model experiment (b), where the wedge-shape model shown in Fig. 2 was adopted as a typical non-axisymmetric nose configuration. The pressure variations with time at a specific position are also shown in Fig. 6. The result of the experiment shows positive pressure at the range of about x>0.15m due to the exfoliation of airflow. Except for this range, both results show characteristics indicated by a non-axisymmetric train model and agree well each other. Especially, it is noteworthy that the slope from positive to negative pressure is different between the observation points.

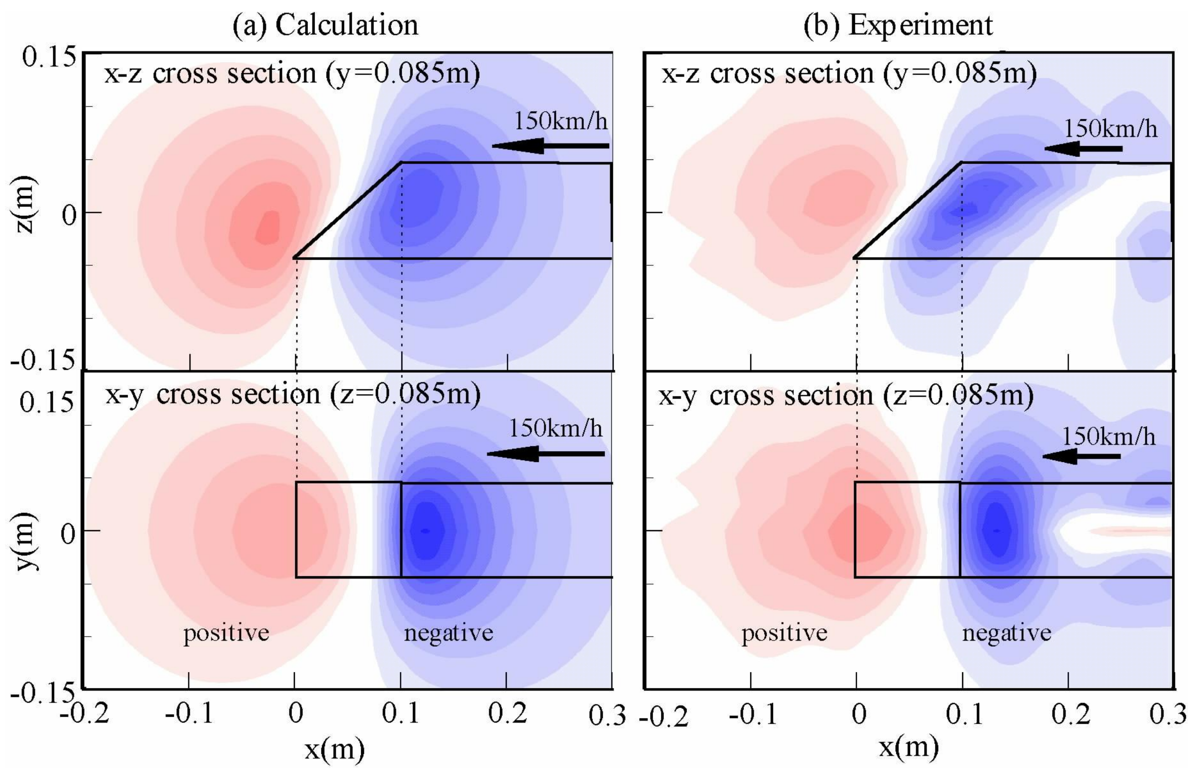

Figure 5: Comparison of the pressure field obtained by numerical calculation (a) and scale model experiment (b).

Finally, the results of the calculation with the characteristics of attenuation of the positive pressure and the negative pressure by distance and direction are shown in Fig. 7. In the vicinity of the track less

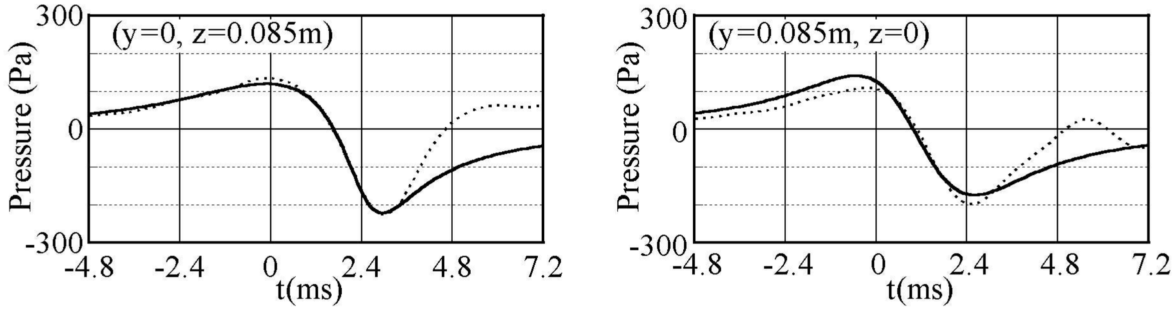

Figure 6: Pressure variation with time (solid line: calculation, dotted line: experiment).

than twice the distance of train width, it can be seen that the pressure field becomes more and more non-asymmetric in correspondence to the nose configuration.

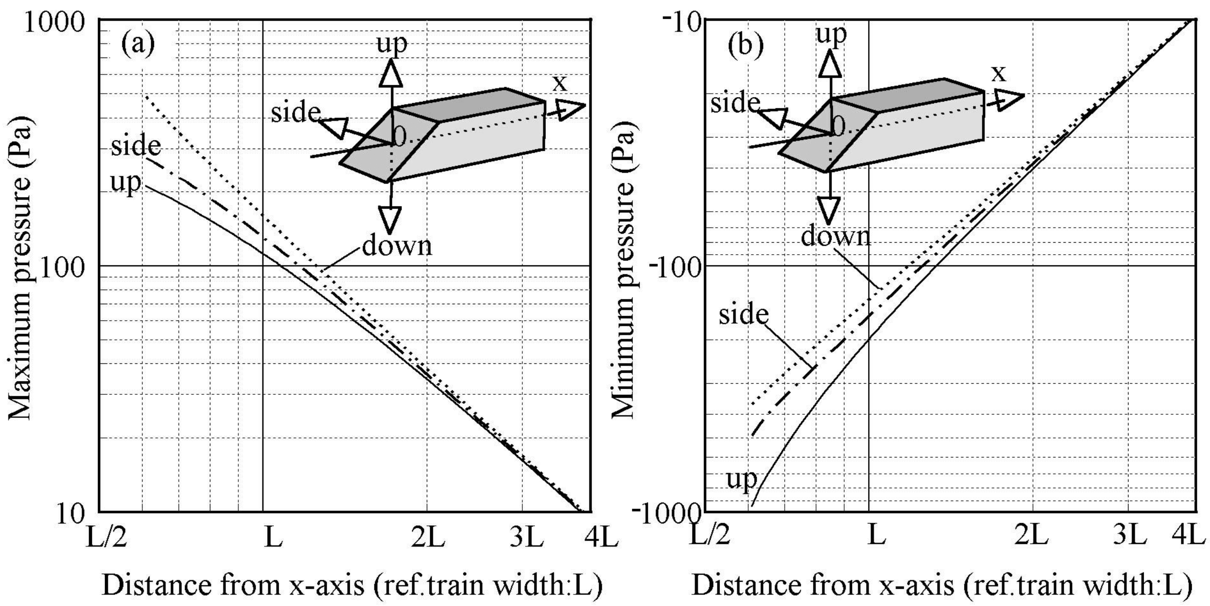

Figure 7: Pressure attenuation by distance and directions (a: positive pressure, b: negative pressure).

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