The Memoirs of Faculty of Engineering
Fukuyama University
The 13th issue, September, 1992

Improved Method for Measuring Pressure Distribution Around Hypersonic Vehicles by Means of Magnetic Tape.

Masatomi NISHIO*

Abstract

This paper has described a new measuring method of the surface pressure distribution around hypersonic vehicles by means of a magnetic tape. This method is based on the following ideas; When a magnetic tape is placed in a magnetic field, the tape is magnetized. The magnetization strength is related to the strength of magnetic field of the place. In a constant magnetic field, if the position of the magnetic tape changes, the magnetization strength of the tape, namely, the magnetization quantity of it also changes. This means that the displacement of the tape can be obtained by measuring the magnetization quantity and that the magnetic tape can be utilized as a diaphragm type pressure sensor. Furthermore, this method can be easily applied to the pressure distribution measurements. As the examples of this method, the pressure distributions around the surface of a flat plate and a semicone body with a delta wing have been carried out successfully.

1. Introduction

In recent years, the study on hypersonic flows has become very important for the necessity of developing space shuttles, hypersonic transports(HST), etc. As for the experimental study, it has been very troublesome as well as very important to measure pressure distributions around hypersonic models, in order to obtain the rift and drag of the models. Because the duration time of the hypersonic tunnels which are generally used in laboratories is usually very short. Therefore, pressure transducers of very short response time, such as the piezo pressure gauge, the strain gauge, etc. have been used. However, these pressure transducers can obtain the pressure value of only one position by one pressure transducer during an operation of the tunnel. In order to measure pressure distributions, since the pressure values of a large number of positions have to be obtained, we have to operate the tunnel by the same number of times as the number of the measuring positions. For this reason, a new measuring method has been required for the measurement of the pressure

*Department of Mechanical Engineering

distribution on the surface of hypersonic vehicles.

Therefore, the author reported the new method[1] for measuring surface pressure distributions by using a magnetic tape. In this paper, the method has been improved for measuring pressure distributions around hypersonic vehicles. The pressure distribution measurements are carried out using a hypersonic tunnel, whose main characteristics are as follows; the freestream duration is 10 msec, Mach number is 10, the static pressure is 100 Pa, and the exit diameter of the nozzle is 150 mm.

2. Experimental Principle and Procedure

The present experimental principle is explained in Fig.1. A magnetic tape used as a diaphragm is deflected according to a pressure subjected to the diaphragm. When an electric current is generated in a lead wire by applying voltage, an electric field occurs around the wire. And the strength of the electric field is related to the distance from the wire. If the diaphragm of the magnetic tape is placed at a suitable position in the electric field, the magnetic tape is magnetized, and the magnetization strength is related to the distance from the wire. Consequently, the value of the pressure subjected to the diaphragm is obtainable by using the calibration curve between the pressure and the magnetization strength.

The electric circuit for flowing electric current to the lead wire is shown in Fig.2. In this circuit, in order to flow electric current, a voltage is applied to the both ends of the lead wire when a trigger pulse acts on the thyratron.

The measuring system of the magnetization strength of the tape is shown in Fig.3. The

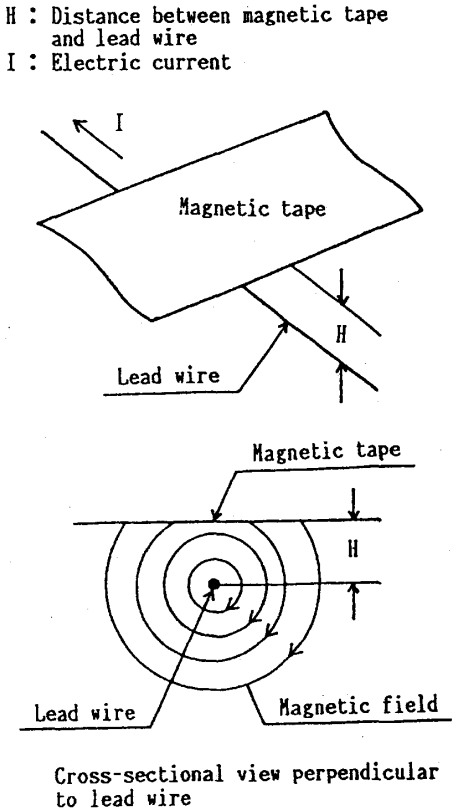

Fig.1 Illustration of visualizing Principle.

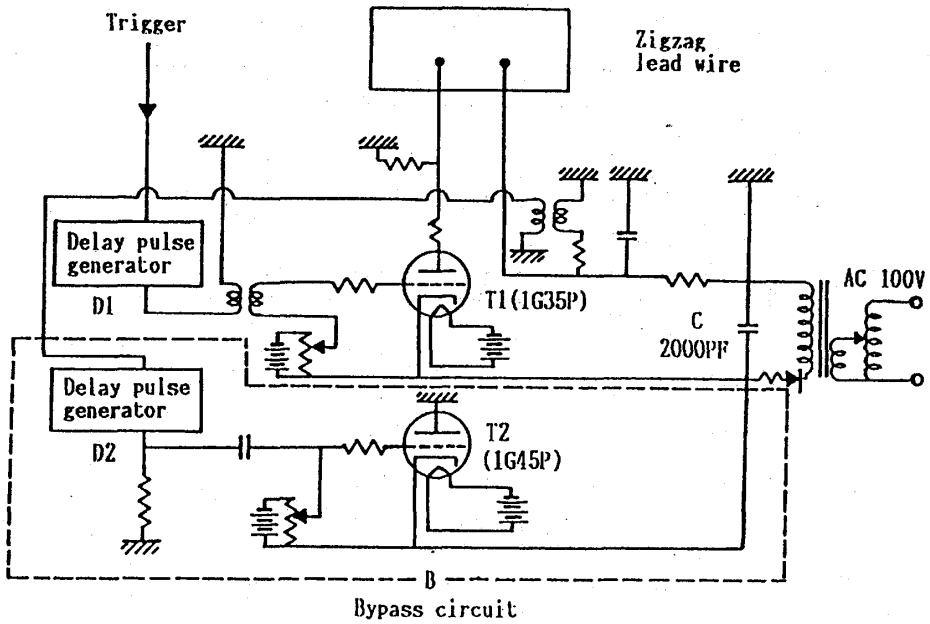

Fig.2 Electric circuit.

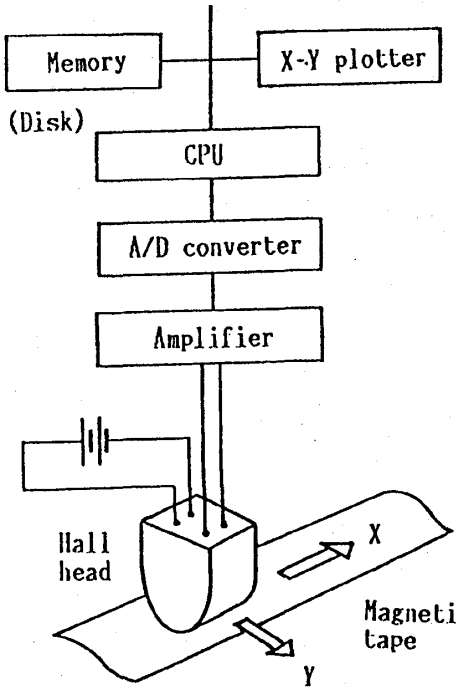

Fig.3 Measuring system of magnetization strength of tape.

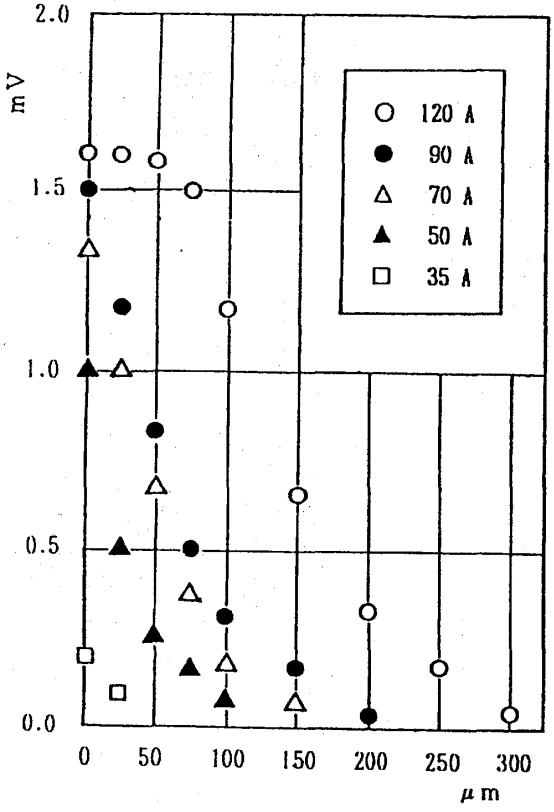

Fig.4 Relation between output Votage and distance of lead wire and the magnetic tape under parameter of electric current in lead wire.

output voltage is obtained by sliding the magnetic recording head MH—6W—DO—7H on the surface of the tape.

Next, the author investigates the relation between the output voltage and the distance of the lead wire and the magnetic tape under the parameter of the electric current in the lead wire. The experimental result is shown in Fig.4. The result indicates that when the electric current

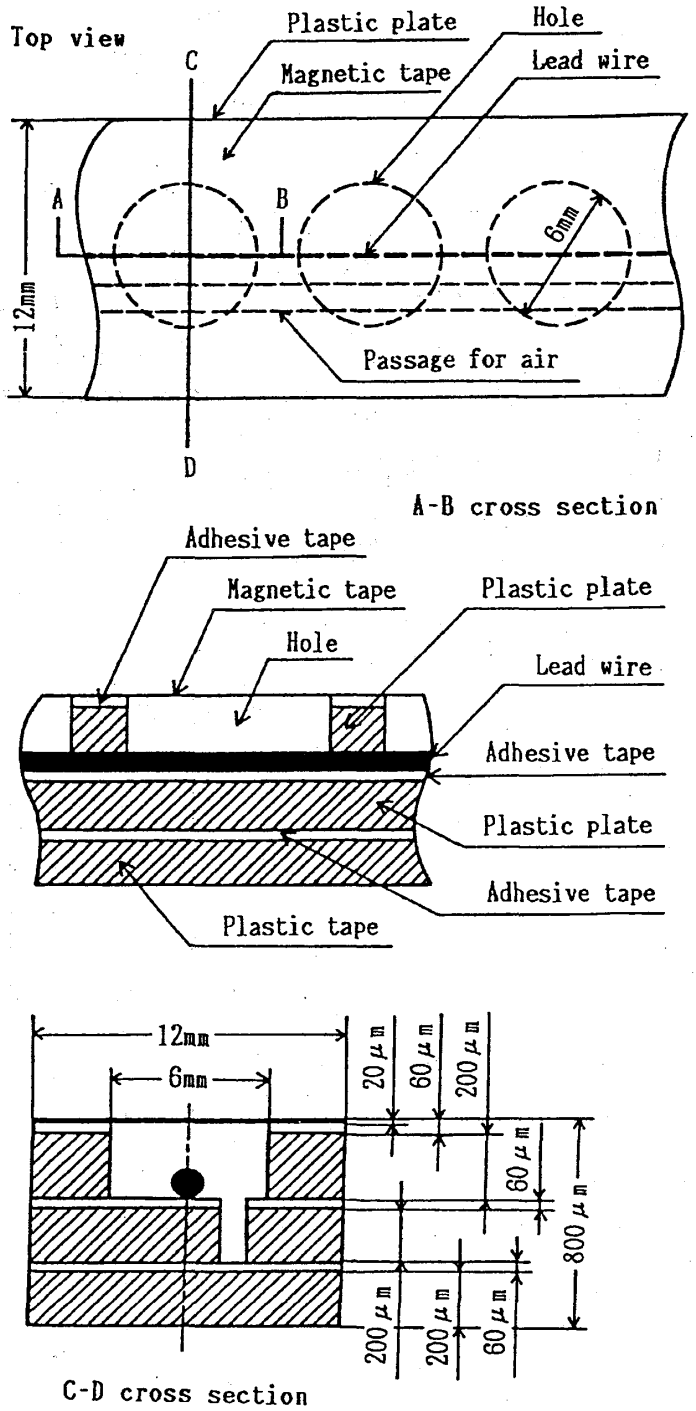

Fig.5 Pressure transducers designed and used in these experiments.

is too small, the output voltage is also too small, and to read the voltage becomes more difficult. On the other hand, when the electric current is too large, there occurs the possibility of saturation of the output voltage. From these results, the electric current of 50 A is used throughout these experiments.

Fig.5 shows the pressure transducers designed and used in these experiments. It is very easy to make a large number of such pressure transducers in a sheet as shown in the figure. When we read the magnetization quantities, the values of these many pressure transducers are readable at a time easily. Further, a measurement of a pressure distribution can be performed

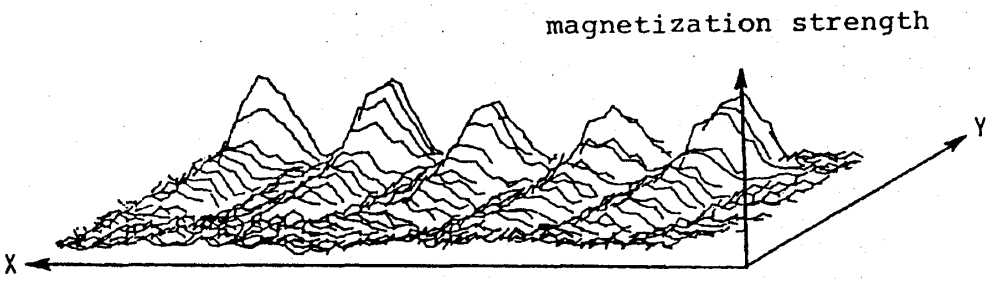

Fig.6 Example of distribution of magnetization strength on surface of magnetic tape.

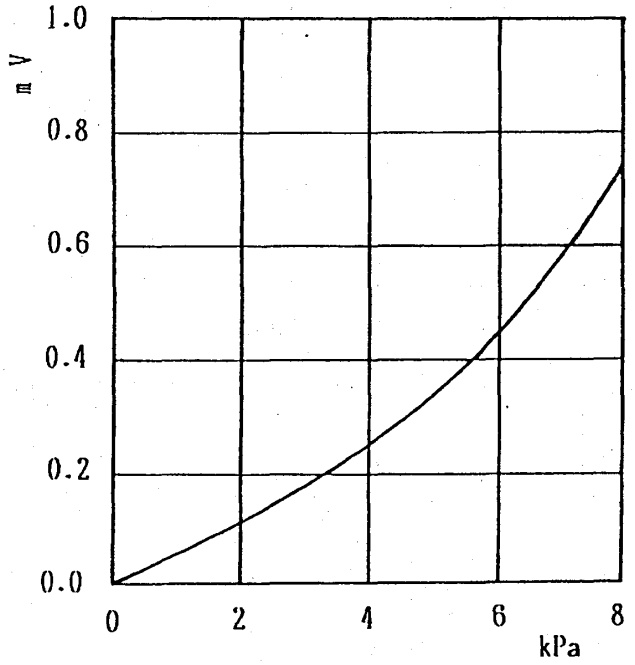

Fig.7 calibration curve.

by just putting the sheet which contains a large number of the pressure transducers on model surfaces. Therefore, it is very suitable to apply to the measurement of pressure distributions. An example obtained by measuring the distribution of the magnetization strength on the surface of magnetic tape is shown in Fig.6. In this experiment, a uniform pressure is applied to the diaphragms of the five pressure transducers in the sheet. Since the lead wire is arranged in the center of the diaphragms, the magnetization strength becomes the largest at the center of the diaphragms because the deflection of the diaphragms becomes the largest at the center of them. The value of the pressure can be obtainable by using the calibration curve shown in Fig.7.

3. Pressure Distribution Measurements

As described in the introduction, it is troublesome to measure pressure distributions on the surface of bodies in experiments using hypersonic tunnels. So, the author performed the experiments of pressure distribution measurements by using the present pressure transducers.

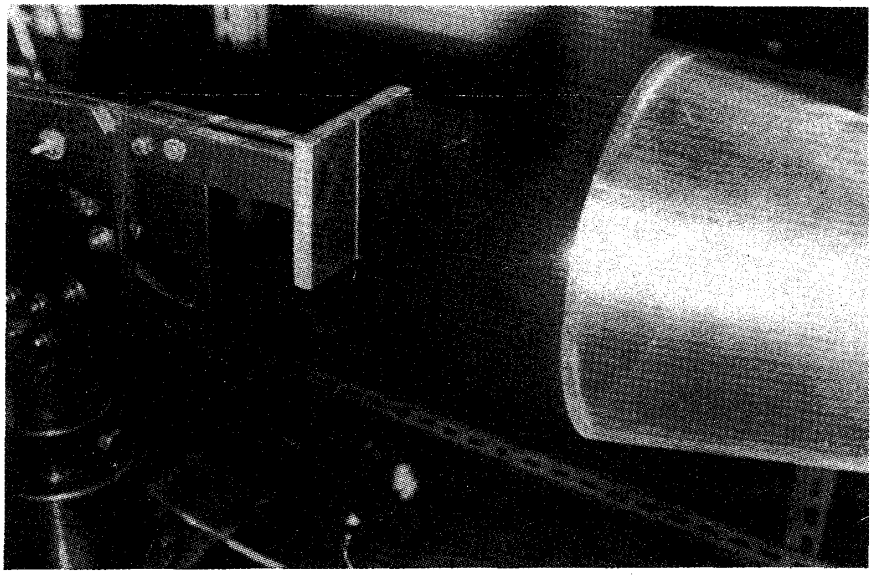

Fig.8 Test section including flat plate placed perpendicularly to hypersonic flow.

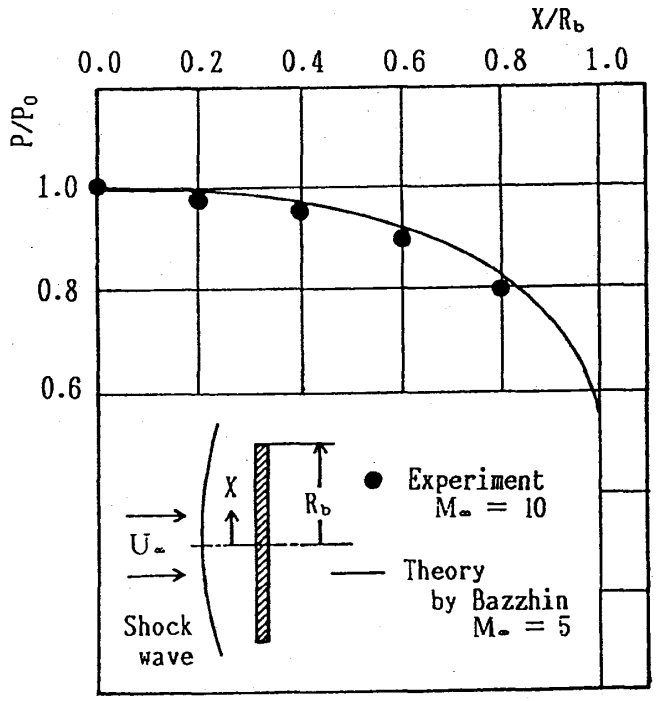

Fig.9 Pressure distribution on surface of flat plate.

First, the pressure distribution on the surface of a flat plate is measured. Fig.8 shows the test section including the flat plate placed perpendicularly to the hypersonic flow. We can see the sheet put to the model surface. In this sheet, the five pressure transducers are contained. The result of the measurement is shown in Fig.9. The calculation result using the Integral Relation by Bazzhin[2] is also shown in Fig.9. The figure shows that both the results agree comparatively well with each other. From this result, it is considered that the present method is usable for the measurement of pressure distributions.

Next, the author measures the pressure distribution on the surface of a more complicated model shape. The model is a half cone with a delta wing. This model is known as a fundamental figure of hypersonic vehicles. The semiapex angle of the cone is 15o and the

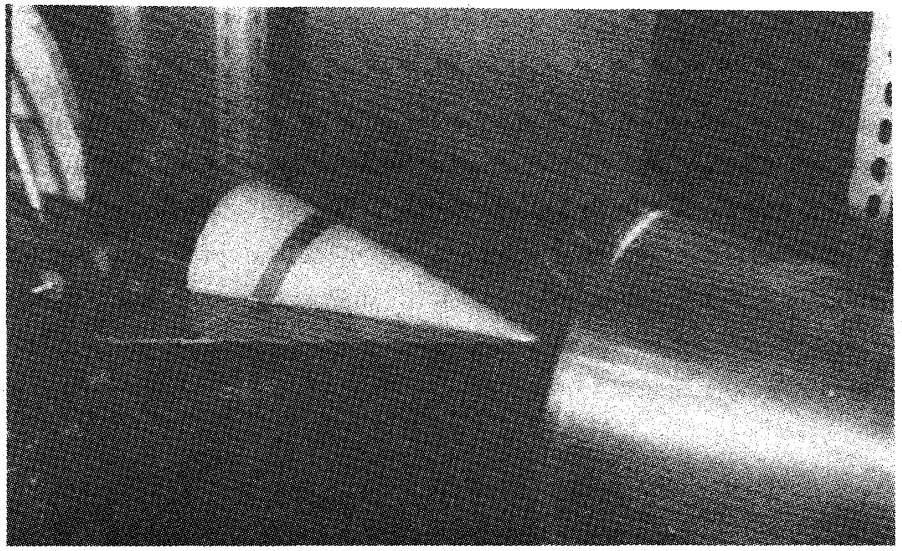

Fig.10 Test section including half cone body with delta wing.

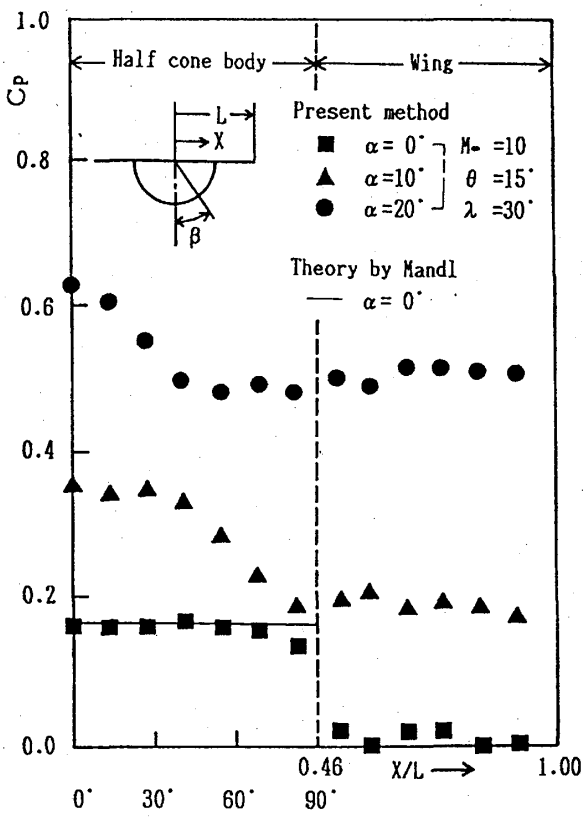

Fig.11 Pressure distribution around half cone body with delta wing.

semiapex angle of the wing is 30o. The test section including the model is shown in Fig.10. The result of the measurement is shown in Fig.11. The theoretical result by Mandl[3] is also indicated in Fig.11. Fig.11 shows that both the results, the theoretical and experimental ones, agree well with each other. From this result, it is considered that the present method is usable for the measurement of pressure distributions on the surface of complicated model shapes.

4. Conclusion

Pressure distribution measurements were performed by utilizing the magnetic tape. The hypersonic tunnel was used as the wind tunnel. The models used in these experiments were the flat plate and half cone body with a delta wing. The experiments were easily carried out by just putting the sheet containing a large number of the pressure transducers. These measurement results agreed comparatively well with the theoretical ones. From these results, it is confirmed that the present method is suitable for the pressure distribution measurements in the experiments using hypersonic tunnels.

References

[1] Nishio, M. et al ,"A New Method for Measuring Surface Pressure by Means of Magnetic Tape", Transactions of Japan Society of Mechanical Engineers, Vol.56, No.532, 1990, pp.3799—3804.

[2] Bazzhin, A.P.,"On the Calculation of Hypersonic Gas Flow Past a Flat Plate with a Detached Shock Wave", Inzhen, zh.,Moscow 3, 1963, pp.222—227,

[3] Mandl, P.,"A Theoretical Study of the Invicid Hypersonic Flow About a Conical Flat—Top Wing Body Combination", AIAA Journal, Vol.2, No.11, 1964, pp.1956—1964.