Form 2

Dissertation Abstract

Report no.	(Course-based) No. 1038	Name	SHAHAJADA MAHMUDUL HASAN
Dissertation title	Development of a Wind Tunnel System Using Magnetically Suspended Ball (磁気浮上式回転球体風洞装置の開発)		

Abstract

This research is entitled "Development of a Wind Tunnel System Using Magnetically Suspended Ball".

Magnetic suspension technology has shown a great deal of promise for manipulation tasks. Due to the lack of mechanical contact, magnetic levitation systems are free of problems caused by friction, wear, sealing and lubrication. These advantages have made magnetic levitation systems a great candidate for various kinds of applications. Magnetic suspension provides an ideal way of supporting a model for wind tunnel tests because there is no support interface problem arising with mechanical model support.

A wind tunnel system for spinning body to measure hydrodynamic forces acting on the body has been fabricated. In this system, the body is suspended and rotated by electromagnets. The experimental apparatus has eight electromagnets which are placed around a 60mm × 60mm wind tunnel. To detect the three dimensional position and control of the floator, an optical displacement sensor has been developed. Stable levitation has been achieved by applying PID control. Rotation of the body has been realized by superimposing two-phase AC signals on the control signals for the horizontal directions and thus rotation in vertical direction has been achieved.

However this existing arrangement is not still appropriate to observe accurate hydrodynamic phenomena around the floating object and it is required to enlarge the size to reduce the interferences with the walls. The variation of the force with the increase of current through electromagnet is also required to estimate aerodynamic forces accurately. It is also important to understand the capability of the floator to be levitated in the suspended condition during the airflow. Electromagnetic analyses are carried out and the magnetic force acting on the floator is estimated. The variation of that force with the increase of current in electromagnets is also obtained. Experimental results support the results obtained by analysis. The distribution of magnetic flux is also studied. The difference of the magnetic force between the upper and lower surface of the floator compensates the weight of it and it is ensured that the sufficient amount of force for levitation was produced. The magnitude of current constant in different directions was also estimated, which is important for the controller design and evaluating the aerodynamic properties properly. It was also observed that there is no interference between horizontal and vertical control forces. For the design and fabrication of the new system, these things are important to understand before the actual development of the system.

A new wind-tunnel system of 100×100mm is designed and fabricated. The floator is made of ferromagnetic material. It is suspended and rotated by the electromagnets arranged outside the tunnel. In designing the system, wide-gap suspension and position sensing are major considerations because both the electromagnets and sensing devices are set outside of the tunnel. In this system the gap in vertical plane where floator is placed is 120 mm. Three dimensional position sensing and control of the floator is done. Wind flow is considered to be in the negative x-axis direction. For compensating the effect of the wind flow, force in the opposite direction is necessary. To make a significant difference of the resultant horizontal force in this direction, the poles are arranged asymmetrically, which is a special characteristic of this design.

Mathematical modelling of the system is done considering the forces acting on the floator in horizontal and vertical directions.

Before the development of the system, the electromagnetic analysis for the system has been carried out. A 3D model of the arrangement is taken in consideration for the analysis. The magnetic force acting on the floator is estimated. The variation of that force with the increase of current in electromagnets is also obtained. The magnetic flux distributions as well as magnetic force acting on the suspended object are obtained. The magnetic flux densities are analyzed for the variation of current in electromagnets. Actual force acting on the body is also measured. It is observed that the experimental results support the results obtained by numerical analysis. Stable suspension and three-dimensional positioning of the body is achieved by IP-D control in the newly developed system. Spinning of the body is realized by superimposing two-phase AC signals on the control signal.

A small wind tunnel is designed and fabricated based on the test section as 100×100mm. The total length of the tunnel is 156 cm. Including the test section, it has total 5 sections: settling chamber, contraction cone, test section, diffuser and drive section. Each of the sections are designed separately.

The hydrodynamic forces acting on the spinning body is to be measured. As IP-D control is applied in this experiment, the fluid drag and lift force can be measured from the control input directly. By varying the wind speed, variation of these forces is also to be observed.