A STUDY ON THE STRUCTURAL MECHANISM OF THE AUTOMATED RADIOSONDE SYSTEM (ARS)

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Abstract - **Meisei Electric has developed an automated radiosonde system (ARS) for upper-air sounding. It has started its first operation at Ishigaki Island Station, Japan (WMO Station ID: 47918) in March 1, 2006. The system design is based on the wind simulation to ensure that the structural mechanism provides stable launches even at the critical weather condition such as rainstorm, typhoon, and so on. The wind tunnel tests have been performed with a model of the launcher, which is equipped with movable wind protector and arc bearing guide mechanism to prove the stability and reliability of the designed system. We present a detailed report on these mechanisms, wind tunnel test and other case study in the following section.**

Keywords – Upper air observation, automated radiosonde system (ARS), wind tunnel test.

I. INTRODUCTION

An Automated Radiosonde System (ARS) operates automatically in all weather condition for the measurement of meteorological variables such as pressure, temperature, and humidity. Generally, the radiosonde is launched manually (hand-launched), which is labor intensive procedure. The strong surface wind is unfavorable condition for the smooth launching the radiosonde. Typhoon is very common in Japan and it is considered as a sever problem faced at the time launching the radiosonde. In order to alleviate these problems, we developed the Automated Radiosonde System (ARS) equipped with movable wind protector and arc bearing guide mechanism that is best suited for smooth, safe, and reliable launch during the typhoon as well. The most attractive feature of the system is that the wind protector (cap like a structure), which rotates automatically to protect the wind pressure after receiving a feedback from wind direction finder.

II. ARS

2.1. System Design

MEISEI’s ARS automatically sets up the radiosonde and performs pre-flight check followed by filling the gas inside the balloons. It also launches radiosonde automatically. The ARS then automatically receives radiosonde signal and GPS satellite signals and convert it to observe data and meteorological message to forward them to JMA and WMO. The ARS is cost effective system for remote locations such as difficult to work, difficult to travel, and difficult to provide manpower.

The external outlook of ARS is demonstrated in Fig. 1 and the system design is shown in Figure 2. The ARS consists of sonde cassette, gas storage, daisywheel, gas filling monitor and control, and launching platform.

2.2 ARS Operation

ARS operation is briefly explained as following. Firstly, loading the radiosonde, unwinders, parachutes, and balloons into the built in cassettes is performed. Secondly, the cassettes are inserted in the daisywheel, which is equipped with positing a control sensor automatically connects the radiosonde cassette to the gas inlet position. Thirdly, the gas is filled inside the balloon by carefully monitoring the amount of loaded gas, gas filling speed and ascending force. Finally, ARS confirms the preflight test and automatically releases the balloon with a radiosonde.

Fig. 1 External Structure of MEISEI ARS

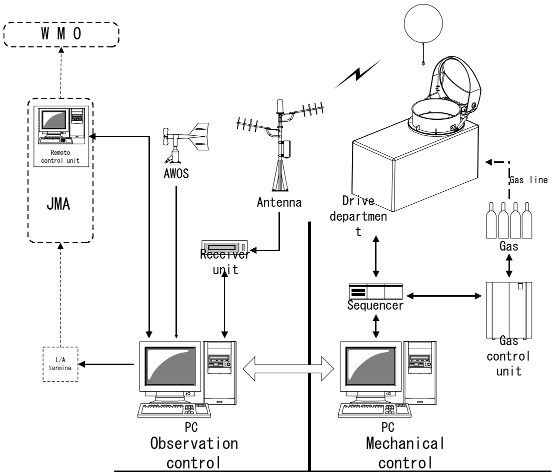


Fig. 2 System design and data flow of MEISEI ARS

2.3 GPS radiosonde

The GPS radiosonde system consists of gas filled balloon, parachute, suspension, and radiosonde system that is operated by battery. The sensors are the thermally sensitive resistor type thermometer, the thin film capacitance humidity sensor, and the GPS signal sensor. The received GPS signals are highly precise, and the accuracy of the temperature and humidity sensor is very high.

We have developed a new GPS radiosonde for ARS to operate automatically and safely. Parameter setting of the radiosonde is performed remotely by software. Gas is automatically filled and stop with the special valve made of plastic material because high precaution has been taken for any possible gas hazard and other accident. New radiosonde system has provision to put the parachutes inside the balloon so that space consumed by the balloon, parachutes, suspension is small and easily fit to the cassette on the daisywheel.

In contrast to our previous radionsonde model RS-01[1], the lithium battery (1.5Vx2) with high energy density has been used for the power supply, instead of water activated battery. It has wide range of advantages, such as easily available in the market, low cost, robust to all the extreme weather conditions, long life, and best suited for ARS. Our radiosonde unit is very light and its weight is less than 155 gm including the battery. Consequently, the gas filling can be remarkably saved and of course, the operating cost will be minimized.

2.3 Ground System

The ground system consists of antennas, pre amplifier, radiosonde receiver, work station (PC), and the base line (BL) checker set as shown in Fig. 2. There are two Yagi Antennas (three elements directional antenna), and a Brown Antenna (omni directional antenna), and this antenna arrangement is the most effective and economic to receive the radiosonde signal continuously up to 250 KM range.

The received radiosonde signal by the antennas is fed towards the PRE AMP, which contains coaxial switch, band pass filter (BPF) and LNA (low noise amplifier). The antenna operation is controlled by coaxial switch to acquire the continuous data. The telemetry signal from the PRE AMP is received by the UHF receiver via coaxial cable (50 Ohm), where the RF signal will be demodulated. The FM demodulated signal is further transmitted to PCM decoder at the rate of 1200 BPS via coaxial cable, where the PCM demodulation is performed. On the other hand, the GPS signal received via the differential GPS antenna is send towards the local GPS receiver via coaxial cable. Both the PCM demodulated signal and local GPS signal are combined in the CPU, where the error check will be performed. Finally, the combined raw data from CPU is transmitted to work station (personal computer) for the post processing and display the data by TCP/IP cable.

III. WIND TUNNEL EXPERIMENT

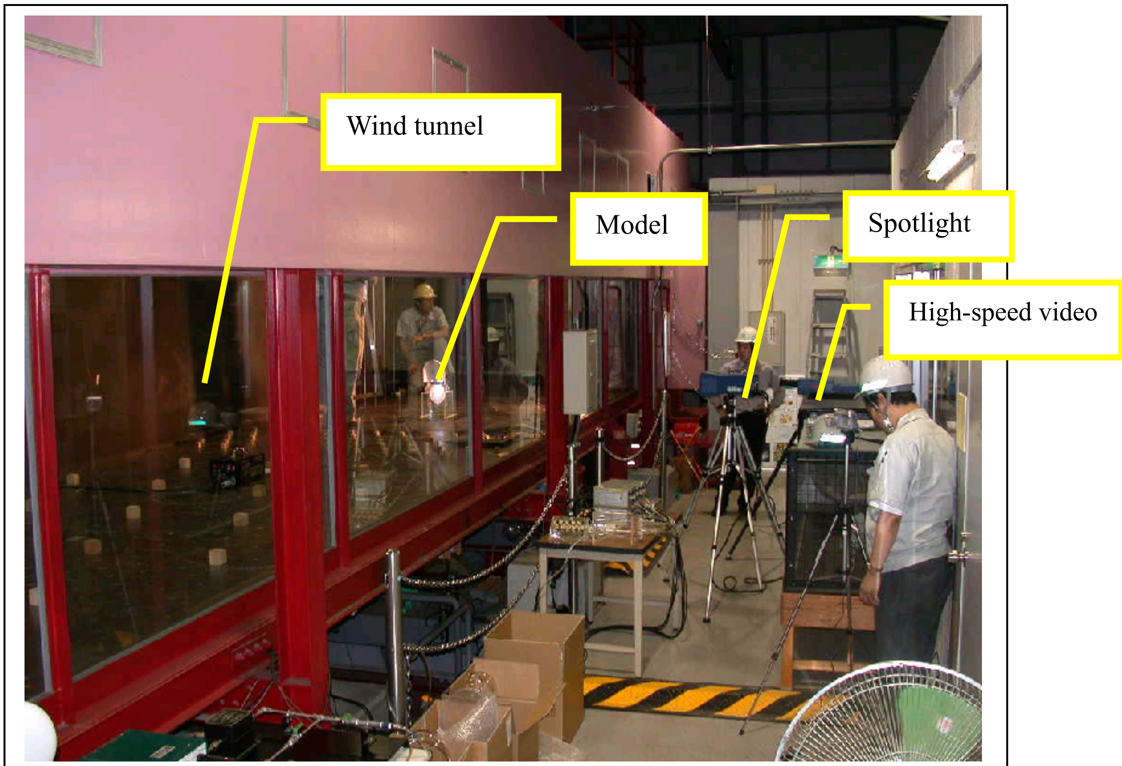


Fig. 3 Experimental Setup for wind tunnel test

We performed the experiment inside wind tunnel to examine the performance of the wind protector, which is demonstrated in Fig.7. The wind is generated inside the wind tunnel by axial type fan system have diameter 3.5 m operated by DC motor (400 V, 150 kw, 0-300 rpm). The total length of the wind tunnel is 94 m and testing area has a dimension of 2.0 m height, 2.4 m width and 21 m length. It has two turn tables of diameter 2.0 m and ceiling height is adjustable. The wind velocity can be varied inside the wind tunnel from 0.5 to 3.3 m.

Generally, our ARS can launch the radiosonde smoothly at the wind velocity 25 m/s or less. However, it is not possible to generate the wind velocity of about 25 m/s. So we generate the wind velocity of about 3.3 m/s and calibrate it using Reynolds Number [2], which is expressed by the following equation.

$$V_a / S_a = V_b / S_b \qquad (1)$$

where, V_a be an actual velocity of wind, which is less than 25 m/s. V_b be a wind velocity inside the tunnel, which is set to be 3.3 m/s. S_a be an actual balloon ascending speed and S_b be the ascending speed of model balloon.

Actual Reynolds Number $R_{e\,Actual}$ and Modeled Reynolds Number $R_{e\,Model}$ can be calculated by the following equations

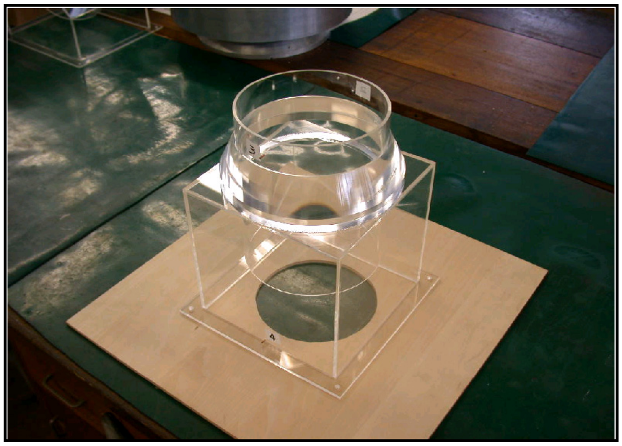


Fig. 4 MODEL-A: Model without wind protector

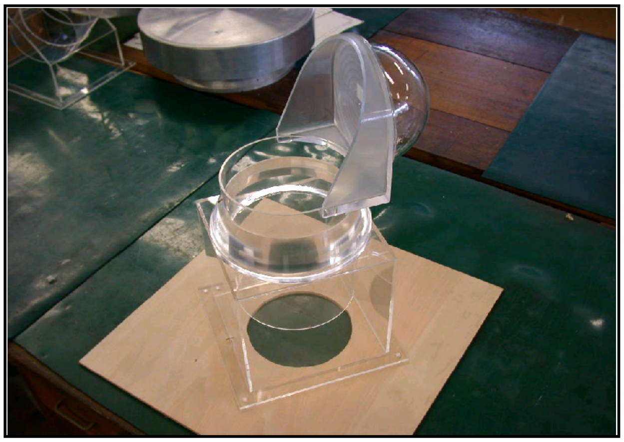


Fig. 5 MODEL-B Wind Protector Model having concavo-convex surface

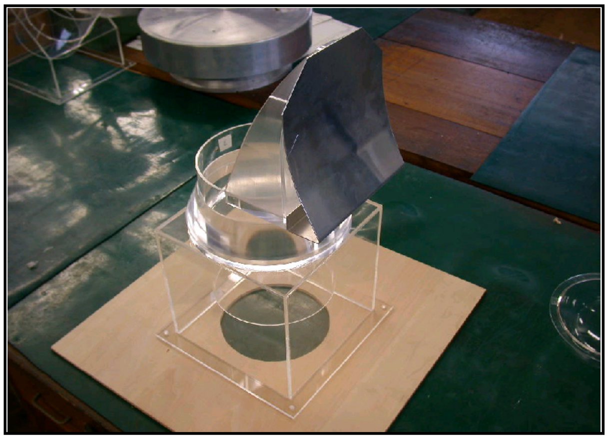
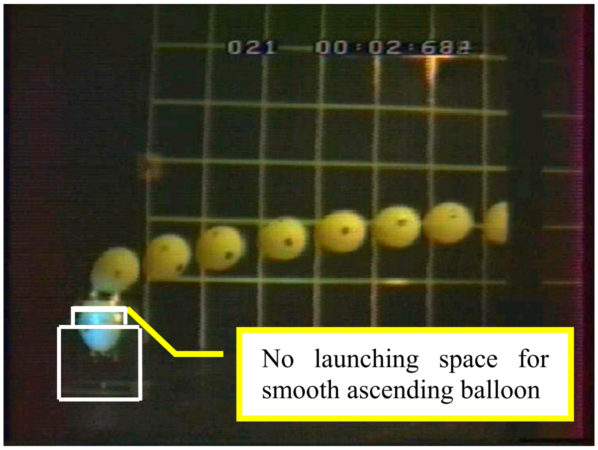
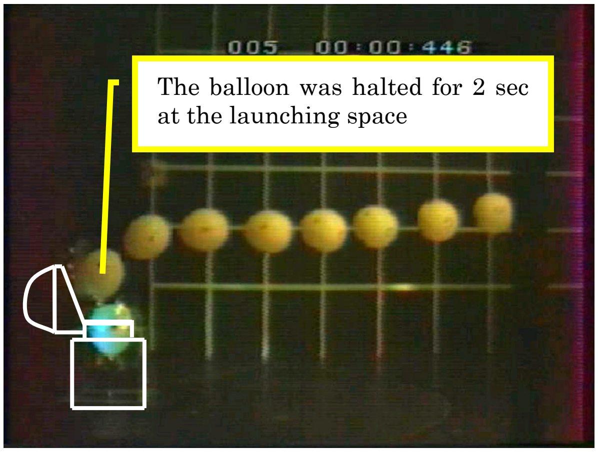


Fig. 6 MODELl-C Wind Protector Model having Plano-concave surface but the upper portion is plane



No launching space for smooth ascending balloon

Fig. 7 MODEL-A: An ascending sequence of the balloon inside the wind tunnel



The balloon was halted for 2 sec at the launching space

Fig.8 MODEL-B: An ascending sequence of the balloon inside the wind tunnel

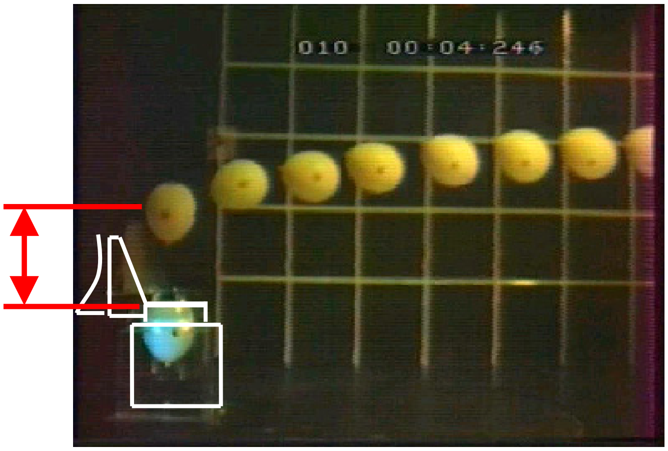


Fig. 9 MODEL-C An ascending sequence of the balloon inside the wind tunnel

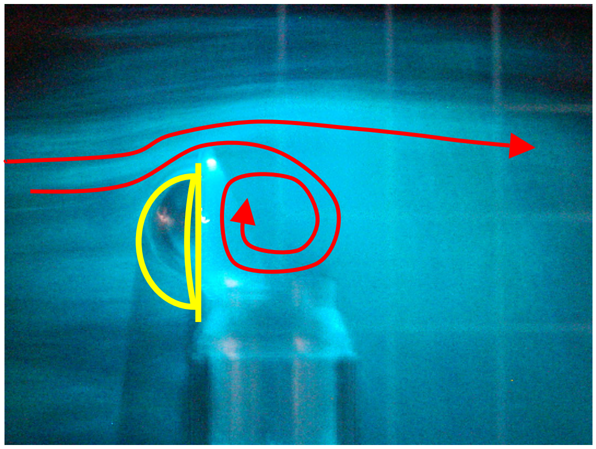


Fig-10 MODEL-B: A: Launching space the wind flow direction

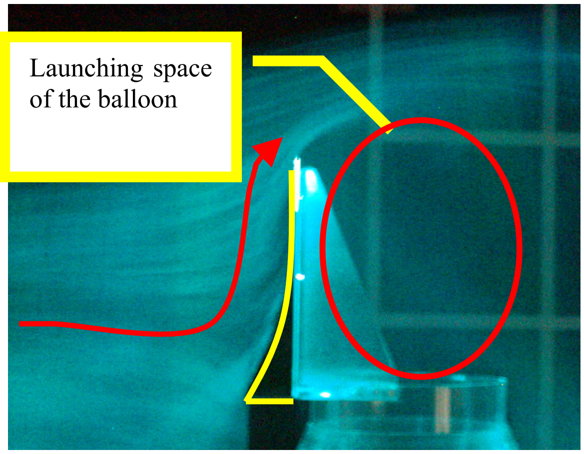


Fig-11 MODEL-A: Launching space the wind flow direction

$$R_{e\,Actual} = UL_{Actual} / \nu = 9 \times 10^{6} \qquad (2)$$

$$R_{e\,Model} = UL_{Model} / \nu = 9 \times 10^{4} \qquad (3)$$

Where,

U : wind velocity

L : height of the wind protector

ν : dynamic viscosity

Here, the modeling scale is 1/12.5 It is found that the discrepancy between the Actual Reynolds Number and the Modeled Reynolds Numbers is not high, which is demonstrated in Eq. 2 and Eq. 3. It is concluded from this experiment that the proposed model can work successfully in actual operation.

It is vital to know the direction and the nature of wind for the smooth launching the balloon from the ARS. The circular wind may stop the balloon at the neck of the ARS and the balloon will not be launched smoothly. Therefore, we made several kinds of wind protector models as shown in Fig 4, 5 and 6. In MODEL A (Fig. 4), there is no provision of wind protector that means there is no launching space for the balloon. So, the launching of balloon is not smooth because the balloon strikes on the outlet of the ARS model several times. In addition, there might be chances that the balloon doesn't come out from the ARS and even the balloon come out, it is flown immediately by the high velocity wind stream. Consequently, slightest friction or strike on the edge of the ARS outlet might cause balloon burst before launching, which is a sever problem of this type of model (see Fig. 7). Secondly, in MODEL B, the balloon was halted for 2 seconds at the launching space due to the effect of circular wind as shown in Fig 8. This circular wind (see Fig. 10) may rotate the balloon in the launching space and the ascending balloon will not be smooth that may cause the radiosonde to strike at the inner surface of ARS.

Finally, in order to combat with such problems, we developed the model of the wind protector which is the best suited for successful and smooth launching of the balloon. It is demonstrated in Fig. 5 (MODEL C). In this model, the wind protector has plano-concave surface but the upper portion is plane. The curve will direct the wind flow in upward direction and mixed with wind profile flown above the wind protector as demonstrated in Fig.12. Thus there was enough launching space for the balloon and the ascending balloon was fully protected from the high speed wind effect and hence the balloon was launched smoothly and safely.

IV. FIELD EXPERIMENT & OPERATION

The field experiment of ARS was successfully conducted at factory premises in December 2005. The first operational of ARS was performed at Ishigaki Island Station, Japan (WMO Station ID: 47918) in March 1, 2006.

Since then, it has been operating successfully even during the typhoon, which is demonstrated by the following data taken during Typhoon No. 4 and Typhoon No. 5 [3] as shown in Table 1 and 2.

Table-1 Typhoon No.4

Date	Time	Wind velocity(m/s)	Launching Result
2006.7.13	12Z	27.7	OK
7.13	12Z	27.0	OK
7.13	18Z	23.4	OK
7.13	18Z	22.6	OK
7.14	00Z	18.5	OK
7.14	12Z	19.9	OK
7.15	00Z	13.8	OK

Table-2 Typhoon No.5

Date	Time	Wind velocity(m/s)	Launching Result
2006.7.24	00Z	7.2	OK
7.24	12Z	9.4	OK
7.25	00Z	8.2	OK
7.25	12Z	10.1	OK
7.26	00Z	8.3	OK
7.26	12Z	8.2	OK
7.27	00Z	7.2	OK
7.27	12Z	5.6	OK
7.28	00Z	3.3	OK

V. CONCLUSIONS

Meisei has successfully developed the advanced ARS for upper air observation. It launches the radiosonde up to 16 times without attendant's assistance.

. The development of wind protector is a milestone towards a development of ARS. The wind protector has ventilating system for smooth and easy outlet of balloon from the launching space. It is based on arch bearing guide mechanism that is best suited for smooth, safe and reliable operation during typhoon. Meisei ARS cassette pack is portable and easy to pack together with the radiosondes, parachutes built in balloons, and the unwinders. Other attractive features of automated radiosonde system are use of lightest lithium battery to extend operating time, accurate GPS height measurement system, environmental friendly biodegradable material radiosonde case, temperature sensor coated with aluminum, and external thin film capacitance humidity sensor, pre-launch base_line check to ensure the reliability of temperature and humidity measurement, and so on.

Since the number of ARS and the available data is limited, more data acquisition and development of advanced ARS is essential that can be used in challenging environment conditions such as snow fall, change of surface wind direction within the short span, would be the topic for the future research.

New installation of ARS will be done in Naze, Kagoshima, Japan within this fiscal year.

VI. ACKNOWLEDGEMENT

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