Technology of Ballistic Parameter Measurement for high Dynamitic Flying fuze

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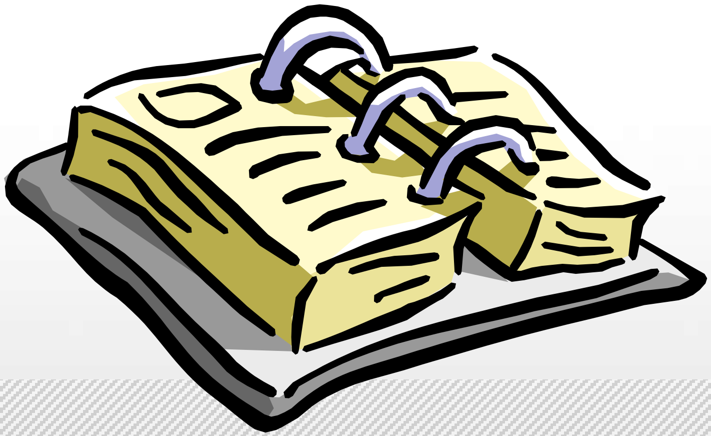


Introduction

The performance of fuze is closely related to the ballistic environment which involves varies forces on fuze during launch, flying, impacting, and penetrating, such as recoil, spin, aerodynamics, gravity and temperature etc. ,as a result acceleration, velocity and attitude are produced. With the technology development of course correction fuze, penetrating fuze and fuze safety system based on sensors etc., the requirements for the measurement of fuze flying attitude and position are urgent, because these parameters are very important for the fuze design.

Introduction

Generally, the techniques of inertial and radar measurement are used for flying attitude and position. But these techniques are limited or impossible for the test of high dynamic fuze (high spin, high acceleration, high velocity). One side, the inertial test technique can‘t be used under the condition of high spin and high acceleration. Other side the test ability of radar will be lowered with smaller target and long flying range.

Introduction

A method of digital solar aspect angle measurement based on telemetry is proposal in this paper, which can be used for testing the altitude of the high dynamic fuse. The relative key technology was researched and a test system has also been developed with the feature of high accuracy, long fly range test and easy use etc., which has a prospect of wide application. The system has been successfully used in the range under different launch conditions for 122 artillery shell and 130 shell, which the solar aspect angle and spin data are obtained on the whole flying trajectory by.

Introduction

Furthermore on the basis of these data, the information of the nutation and precessional of fuze has been acquired and an excellent effect has been achieved. The difficulty problem of the test for ballistic parameters on long range, such as nutation and spin rate, has been resolved. In this paper the system operation principle, solution, composition, specification achieved and confirmation in the range test are presented.

System operation principle

1.1 Definition of Solar Aspect Angle

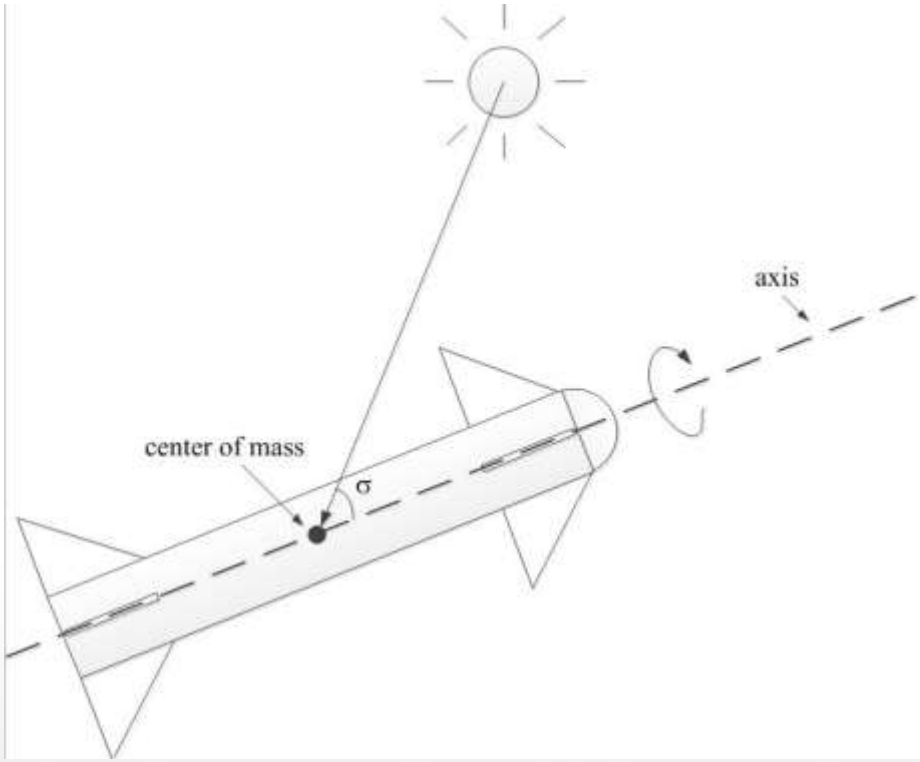


Fig.1 Definition of Solar Aspect Angle

Solar aspect angle,shown in Fig.1 is the angle between the projectile axis and the line from mass center of projectile to the Sun. So the change of this angle reflected change of attitude of the projectile in flight.

System operation principle

1.2 Composition of Solar Aspect Angle Sensor

The sensor of Solar aspect angle is mainly composed of two optic gaps (aperture）, two optic detectors, two Pr-amplifiers and a signal processing unit. Optic gaps are used to form the light path which enable the ray from Sun entering the inner of the projectile. The optic sensing components are used to sense the solar energy which goes through the gaps and then convert it into electronic signal.

System operation principle

- **This signal is then amplified by pr-amplifier to a designated voltage l evel suitable for the requirement of signal processing unit. The pulse signals come from two detectors are processed and encoded by the u nit and its serial output signal as input of telemetering system modula tes the carrier of a transmitter. Then the modulated carrier which incl udes the information of solar aspect angle is radiated to the ground st ation in real time.**

System operation principle

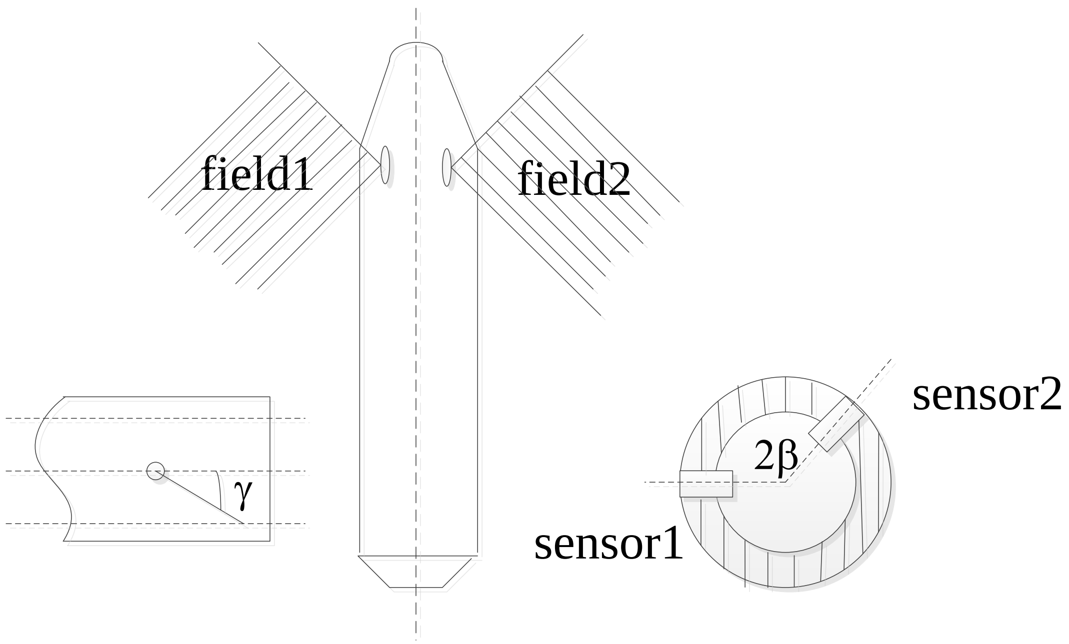


Fig. 1.1 Viewing field and geometric mountingof aspect angle sensor

The field of view of the sensor of solar aspect angle and mounting method are shown as Fig1.1. The fields of view are setup by both optic components and gaps. The two same sensors are mounted on the circle of the surface of fuze in the angle of inclination between the field of view and projectile axis. The angle between two sensors on the cross section of projectile can also be adjusted to a certain angle.

System operation principle

1.3 Mathematic Model of Sensor of Solar Aspect Angle

Based on the mounting method, shown as 1.1, the mathematic model of solar aspect angle sensor can be given by the formula 1.1.

$$\mathrm{tg}\sigma = \frac{\mathrm{tg}\gamma}{\sin\left(\pi \cdot \frac{x}{y} - \beta\right)} \qquad (1.1)$$

Where, σ is solar aspect angle. γ is the angle with either of two field of view to the axis of projectile. β is the half angle between the two gaps. x is the time between two pulse signals output successively by different sensor during once spinning. While, y is the time between pulse output by the same sensor. On the basis of formula 1.1, the function of solar aspect angle σ with time ratio x / y can be setup, in other words, the angle measurement will be converted to the time measurement which is more realizable in engineering. So, the formula is the theoretical basis for measurement of solar aspect angle.

System operation principle

1.4 Principle of Measurement

During the spinning of projectile in flight, the sensor will output a pulse signal when the light vector in the plane of field of view of sensor. So the projectile spins once time, two pulse of sensor will be output. The time between two pulse from the different sensor is x and from the same sensor is y, the radio of x and y is the rolling angle between two sensors. This angle directly reflects the change of attitude of projectile and different altitude of projectile with different rolling angle, shown as fig.1.2.

System operation principle

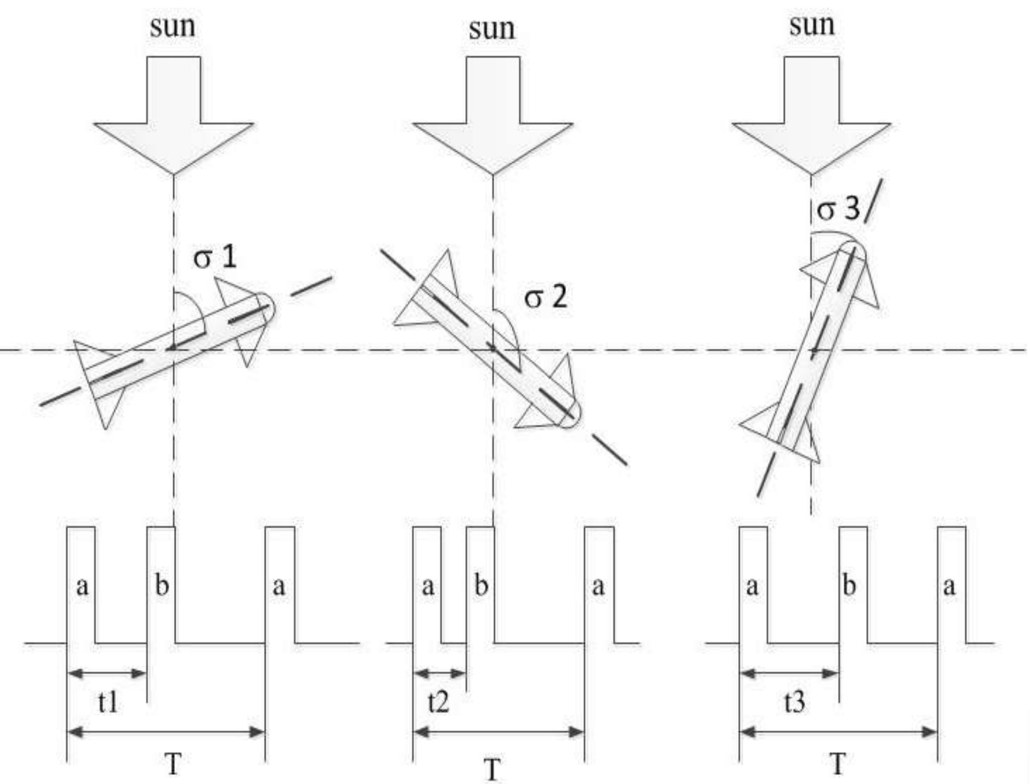


Fig.1.2 Different Altitude of Projectile with Different Rolling Angle

There are two methods to acquire solar aspect angle:

(1) Mounting angles of sensor , γ and β, are measured accurately before test ,bas ed on the time ratio measured in flight s olar aspect angle can be acquired by for mula 1.1.

(2) Base on a simulation system which consists of a sun light source ,a spinning table etc, the relation of ratio and solar aspect angle is calibrated ,the calibration curve of x/y withσis acquired. According to the radio measured solar aspect angle can be determined by the curve

System composition

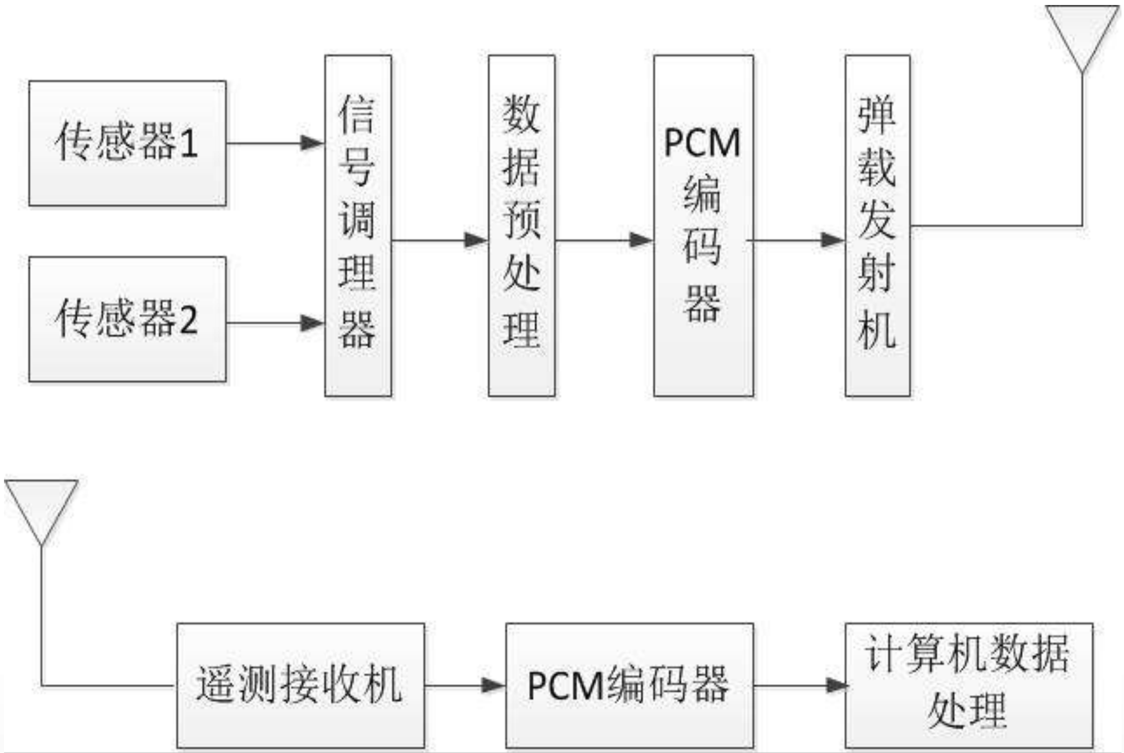


Fig.2.1 System diagram of digital solar aspect angle telemetering

Based on the digital sensor of solar aspect angle and PCM/FM telemetering technology, the measurement system is mainly consists of on board subsystem with the digital sensor and ground subsystem, shown as Fig.2.1. A digital sensor of solar aspect angle is used to measure the time, X and Y, in flight. At the same time these relevant data are transmitted to the ground by telemetering system in real time for processing , displaying and storing.

System composition

2.1 On Board Subsystem

On board subsystem located in the standard fuze body consists of the sensor of solar aspect angle, signal regulator, data pre-processing unit, PCM encoder, S band transmitter and antenna etc.. As mentioned above, on board subsystem is used to process the signal from the two sensors, acquire the time of x and y and encode the time data to form serial PCM data stream according to the pattern of telemetering. The transmitter is modulated by this data stream and transmits the radio signal to the ground station through the antenna. Because time X and Y are processed onboard in real time and converted to the digital signal, the error of transmission can be reduced and accuracy of measurement is improved, which also has many other advantages such as anti-interference and easy realization etc..

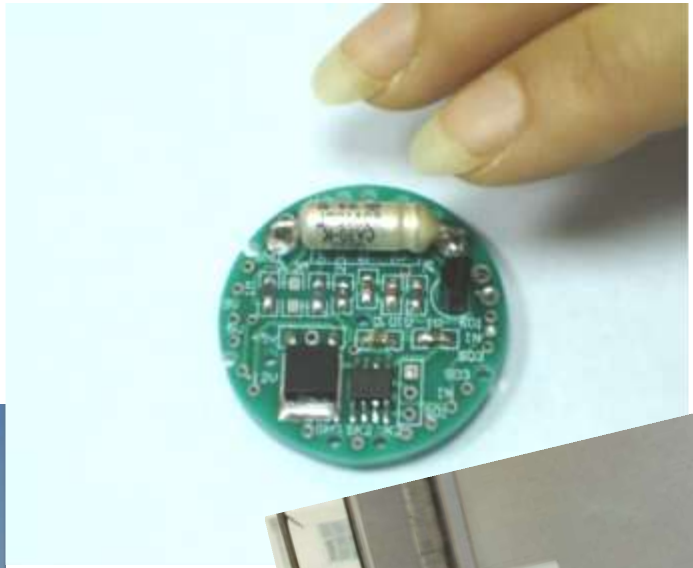
System composition

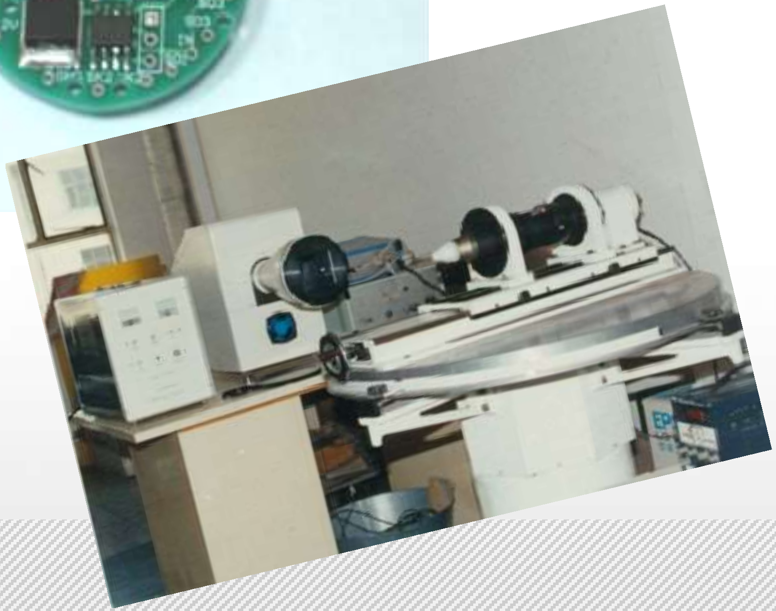
2.2 Ground Subsystem

Ground Subsystem mainly consists of receiving antenna, receiver, digital decoder, computer and sensor of solar aspect angle calibration unit etc.. Receiving antenna is used to receive the radio signal form onboard system. Telemetering receiver is used to filter, amplify and demodulate the radio signal. Digital decoder is used to decode the PCM stream (frame synchronization, bit synchronization and serial to parallel). The whole ground subsystem is controlled by computer to realize telemetering signal processing ,storage and display. The sensor calibration unit is used to test dynamic performance and calibrate the relation of input and output for the sensor of solar aspect angle.

System Hardware and Main Specification

3.1 System Hardware





3.2 Specification

Angle measurement accuracy : ±0.5°

Angle measurement range:

Illumination range: 3000lax-80000lax

Maximum Acceleration: 20000g；

Maximum spin rate: 24000r/m；

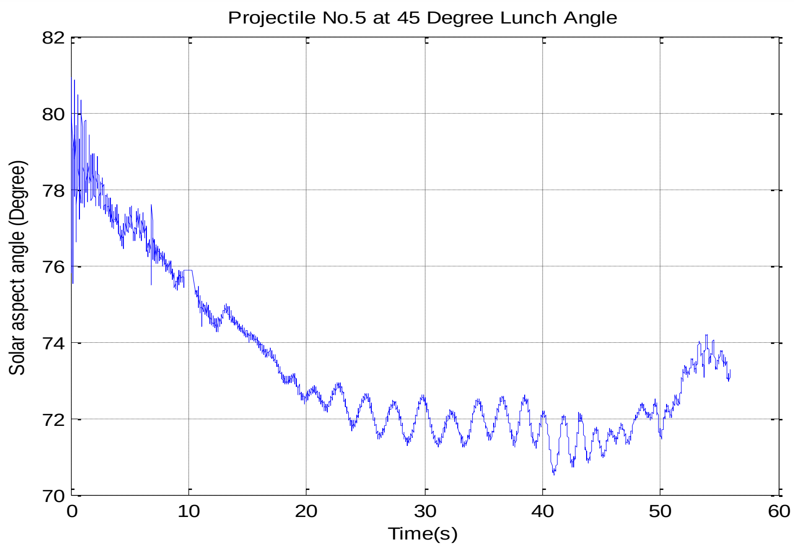
Telemetering system :PCM/FM

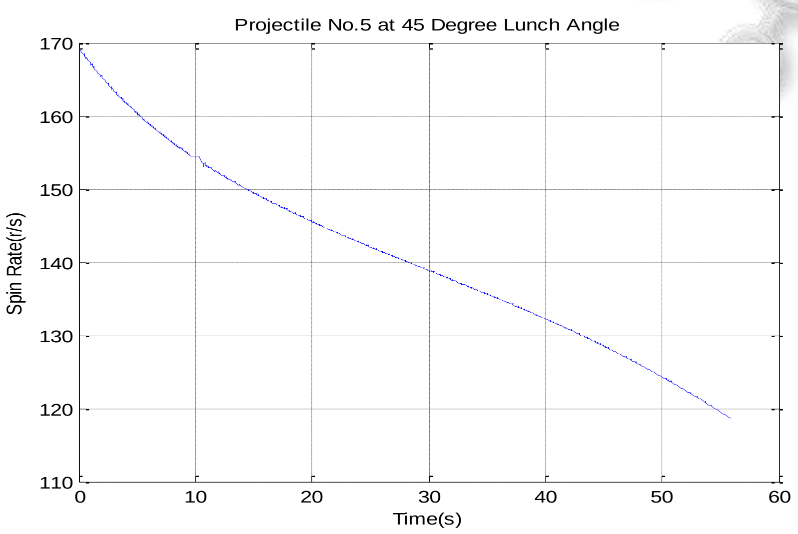
Telemetering Band: S band

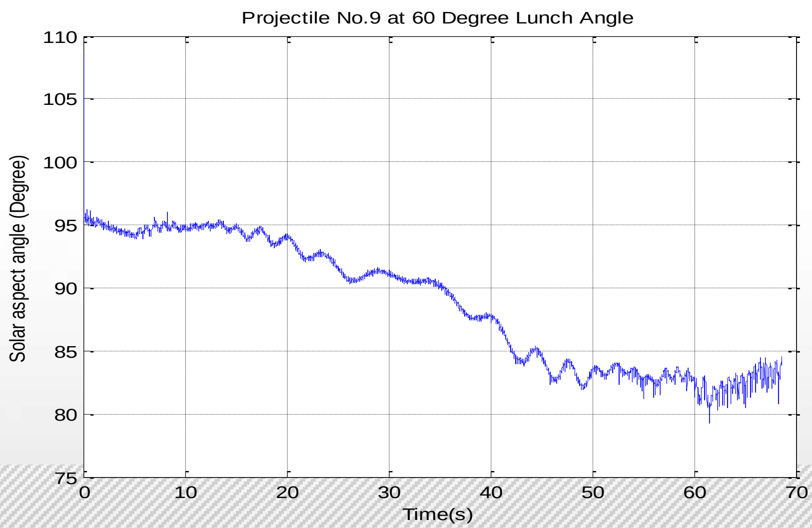
Test Results

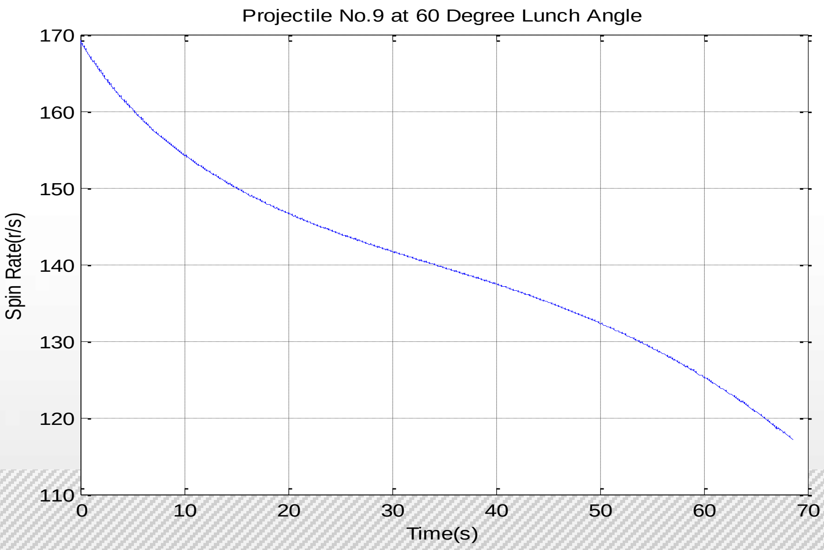
The digital solar aspect angle telemetering system has been developed successfully and used to the range test. The launch platform is 122mm howitzer. The launch angles are 60°and 45°. The launch direction is north to east 17°, the shell flying time is about 58s. All the seven shell with solar aspect angle sensor and telemetering system are operating very well in the test. As a result, the solar respect angle and shell spin data are acquired in long flying path under high g launch condition. Fig.4.1, Fig.4.2 and Fig.4.3, Fig4.4 are respectively solar aspect angle and spin curve form two of the shells.

Test Results









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