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Experimental investigation of heat conduction performance and development of automatic temperature measurement device on modular artillery charge system

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ABSTRACT

The heat conduction performance experiment is conducted on the modular artillery charge system (MACS). Utilizing the experimental measurement system, the change history of the modular charge temperature is obtained. On the basis of the heat conduction performance experiment of modular propellant charge, an unsteady-state heat conduction model describing the temperature change of the MACS is built and the finite-difference implicit schemes are theoretically deduced using the volume equilibrium method for numerical simulation. The validation of the numerical model is checked through compared with the experimental results. An automatic online temperature measurement device on the MACS is developed, based on the non-contact measurement method which is proposed in this paper. As a part of the device, an initial charge temperature sensor (ICTS) is also developed according to the similarity principle. The temperature measurement device where the numerical codes are embedded is assembled in the turret to calculation successively the temperature change of the modular charge with the environment temperature of ammunition rack. Meanwhile, for trajectory calculation and firing data correction, the temperature information obtained from the device may be simultaneously transferred to the gunner task terminal computer through a Controller Area Network (CAN) bus interface.

1. Introduction

At present, a kind of modular artillery charge system (MACS) is required primarily for larger caliber weapon systems (for example, for 155 mm howitzers, etc.). The MACS provides propelling charges with combustible cartridge cases for 155 mm artillery. The charges are compatible with new and existing howitzer systems and offer enhanced precision with a reduction in weight and volume. Meanwhile, the MACS offers maximum flexibility in tactical logistics to warfighters. The build-a-charge system eliminates the need to dispose of unused cartridges, and the charge system fires cleanly, without leaving residue in the cannon breech. Besides the excellent controllability and strong survivability, advanced howitzer systems are required to carry out firing for effect under no fire for adjustment (FFA) in order to realize the coverage of first burst group to target. An important condition to meet these requirements is accurate firing data setting. The charge temperature of the MACS is one of the main tactical and technical indices, and particularly, is a critical firing datum affecting the muzzle velocity and firing accuracy of advanced howitzer systems [1–3]. The influence coefficients of the charge temperature on the muzzle velocity and range are respectively $\partial \boldsymbol{v}_0/\partial \boldsymbol{T} = 0.07\% - 0.10\%$ (m s^{-1} °C^{-1}) and $\partial \boldsymbol{X}/\partial \boldsymbol{T} = 0.12\% - 0.22\%$ (m °C^{-1}), where $\boldsymbol{v}_0$ is muzzle velocity and $\boldsymbol{X}$ is range [4,5]. This means that,

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for a howitzer of muzzle velocity with 1000 m/s, the tolerance of the muzzle velocity and range are respectively 0.7–1 m/s and 45–85 m resulting from a discrepancy of charge temperature with 1 °C for a different type of projectile. Actually, for existing howitzer systems, the measurement tolerance of the charge temperature is generally 3–5 °C using the traditional measuring method [6,7]. Obviously, this measurement tolerance will result in a severe range deviation and has a serious effect on the first round hit ratio [8]. Therefore, improving the measurement accuracy of the charge temperature is an important means in which the firing accuracy, the coverage of the first burst group to target, the operational capacity and the survivability of modern artillery are increased. The MACS composed of several identical propellant charge modules is configured into howitzers. The variations of temperature in the vehicle are wide and unbalanced because of heat emission of motor and heat radiation of vehicle hood. The temperature change of modular charge placed in the turret always lagged behind that of environment temperature. However, there are still no effective methods measuring accurately and rapidly the modular charge temperature which changes with the environment temperature in the vehicle. Thus, it is necessary to study on the heat conduction performance of MACS placed on the ammunition rack in the turret.

An automatic online temperature measurement device is developed for the MACS used to larger caliber weapon systems in this paper. Using the measurement device, the temperature of modular charges placed in the turret of howitzer systems can be successively obtained. The measurement device is composed of a PC104 microprocessor, special calculation software and two sets of the special temperature sensors. The special calculation software, developed on the basis of the unsteady heat transfer equations, can determine the current values of the charge temperature according to the initial charge temperature and environment temperature from two sets of the special temperature sensors and charge character parameters such as the density, heat capacity and thermal conductivity. Two sets of the special temperature sensors are both mounted on the ammunition rack in the turret and used to measure the initial charge temperature and environment temperature in the turret respectively. When the device powers on and begins to work, one set of sensors are used to measure the current values of the charge temperature as the initial values of the charge temperature field and another set are used to measure successively the environment temperature in the turret as the boundary condition of the unsteady heat transfer equations on the charge temperature field. The temperature field and current average value of modular charges are real-time calculated through the special calculation software installed on the device.

2. Heat conduction performance experiment of modular charge

2.1. Experimental measurement system

A measurement system based on real-time data collection platforms equipped with resistance temperature detectors (RTDs) is constructed to measure the heat conduction performance of modular charges. The measurement system is primarily composed of a computer, a universal multifunction data collector and resistance temperature detectors, as shown in Fig. 1. The resistance temperature detector is used to measure the temperature of propellant grains within modular charges along with the changing ambient temperature around them. The resistance temperature detectors selected in this paper are Pt100 sensors, a kind of platinum resistance thermometer with greater stability, accuracy and repeatability as compared to thermocouples. The Pt100 sensor has a resistance of 100 Ω at 0 °C and is by far the most common type of RTD sensor. It has two main types of Pt100 element: wire wound and thin-film. Only wire wound Pt100 elements are suitable for the measurement of the grain temperature because the Pt100 sensors need to be placed into the propellant grains. Wire wound elements consist of a length of fine platinum wire coiled around a ceramic or glass core. These types of Pt100 element are typically 1–5 mm diameter and 10–50 mm in length. The ceramic or glass core can make them fragile and susceptible to vibration so they are normally protected inside a probe sheath for practical use. The RTD-2-1PT100KN2528 series Pt100 sensors manufactured by Omega Engineering, INC. are used to measure the temperature of propellant grains. This type of Pt100 sensors with 2.8 mm dia × 25 mm long wire wound Pt100 elements have a measurement range of -100 to $+350$ °C and a temperature tolerance of $\pm(0.15 + 0.002 \times T)$ °C. The Pt100 series RTD is mounted into the propellant

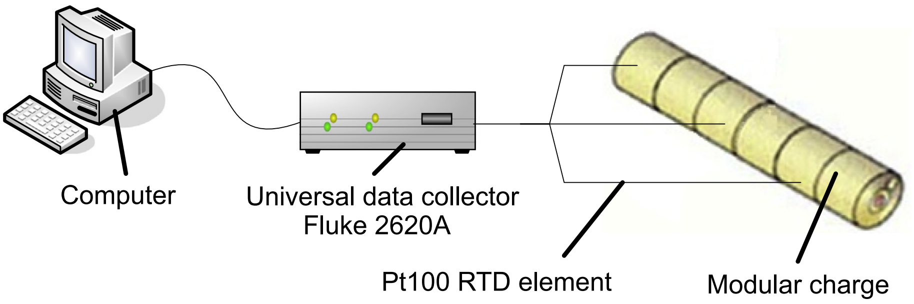

Fig. 1. Schematic diagram of the temperature measurement system of modular charge.