Measurement of Tank Cooling Airflow Based on Array Sensors

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Abstract. Researching on the cooling airflow characters of tank will be helpful for optimizing the design of cooling system, and will be of great importance to improve the performance of armoured vehicles. According to the test requirements of tank under the actual working conditions, we studied and designed the proposed cooling airflow measurement system. The most important thing was that we finished the assembly of array sensors without any damage to tank. In addition, according to national standard we set the quantity and locations of the sensors, which was on the premise of avoiding the influence to airway. In this paper, there was description of cooling airflow signal processing; and there was analysis of air pressure distribution which was presented simultaneously by three-dimensional surface graph and plane graph at the exhaust port of tank engine compartment according to fitting algorithm.

Key words: Tank Cooling Airflow; Array Sensors; Assembly; Signal Processing; Fitting Algorithm; Air Pressure Distribution.

1. Forewords

In modern warfare armoured combat systems are required with greater mobility, for which performance of tank engine compartment is the dominant factor \[1\]. Researching on cooling airflow characters will be helpful for optimizing the layout of engine compartment and the design of cooling system, and for reducing thermal load of engine compartment. The researches will be of great importance to improve the performance of armored vehicles \[2\]. Therefore, there is an urgent need for analysis methods of tank engine cooling airflow performance used in engineering applications.

Measurement system of cooling airflow characters in armored vehicle power compartment was designed in \[2\]. The system was used to measure the air velocity and flow at the cooling air inlet with different speeds of the cooling fan.

In addition, numerical simulation has been developed rapidly as an effective method for airflow and heat transfer researching in recent years \[3\textsuperscript{−}5\], however, its application in research on tank airflow and heat transfer is not mature enough, it is necessary to solve a series of theoretical and technical
problems. The study of airflow and heat transfer in engine compartment must be subject to its own characteristics of tank and be special treated [1].

Different from numerical simulation, we have carried out the measurement of pressure parameters under actual vehicle conditions. In [2], there was measurement of parameters at the air inlet, different from which, we measured the parameters of cooling air at the exhaust side of the engine compartment for further calculation of heat taken away from the engine compartment by cooling air and heat dissipation efficiency of engine compartment.

2. The composition of array sensors measurement system
According to the test requirements of tank under the actual working conditions, which were poor conditions like wide temperature range, electromagnetic interference, and inconvenient assembly for tank measurement in dynamic process, we studied a feasible and reliable test method for tank parameters and has carried out studies such as the design of the cooling airflow acquisition system, the arrangement and assembly of array sensors. Besides we made certain emergency measures and spares which improved the feasibility and reliability of the long time and effective outfield tests in power supply, circuit connections, signal acquisition and storage.

2.1. The Overall Structure of System
Cooling airflow measurement system based on array sensors was mainly composed of a host computer, array sensors, air pressure conditioning circuits, data acquisition and storage system, power supply system, conversion connection system. The overall structure of the system was shown in Fig.1.

2.2. Components of System
We used special software in the host computer to configure sampling frequency, sampling time, sampling volume, sampling channels and other relevant parameters of data acquisition and storage system before the measurement; to preserve and segment data after the measurement for later data processing; or to format.

The power supply system, data acquisition and storage system, conversion connection system, these three parts were fixed in a sealed box made of iron which was used for anti-electromagnetic interference. We used shielded multi-core cable for configuration of host computer to the data acquisition and storage system, for power supply to sensors and air pressure conditioning circuits, and for signal transmission of air pressure conditioning circuits and data acquisition and storage system.

A 12V / 60AH battery was used for power supply system, and there was a spare one.

64-channel storage technology was used for multi-channel data acquisition and storage system which was specially developed for the measurement system, and was very small in volume to save more space for assembly.

The specially developed circuits in conversion connection system were used to change electrical parameters provided by the battery to electrical parameters which sensors, chips and circuits needed.

Air pressure conditioning circuits were fixed inside a specially made aluminum box which was sealed for anti-electromagnetic interference and accurate measurement. The signals of micro-pressure sensors were transmitted to air pressure conditioning circuits, then the signals of circuits were transmitted to the data acquisition and storage system, so that noise from environment and circuits could be reduced.

It was difficult for assembly of the measurement system as any damage to the tank body should not be allowed; of course drilling a hole was not allowed. In this case, we designed mounting fixture specifically to conform to the idle screws of tank; the sealed box made of iron was designed to be the same size as the original spare box of tank, and then we made the replacement; at the same time, some reasonable anti-vibration measures were added for protection.
3. Design of array sensors

Under the dynamic conditions of tank, we eliminated measurement of air hood and adopted the distributed measurement. We selected multiple measuring points of the rectangular cross section at the cooling air exhaust side of tank engine compartment, and then air pressures in different regions were tested at the same time. After the air parameters acquisition by multi-sensor, data were studied with algorithms for tank cooling airflow.

Since the airflow conditions of the inlet and outlet would not be obstructed, it was very important to set the quantity and locations of sensors, and the assembly and fixation were also important.

According to [7], the number of lines (parallel to the small side) and the number of measuring points on each line are both not less than 5 in the case of rectangular section; if the aspect ratio of rectangular section differs greatly from 1, there should be more than 5 lines.

It was important to note that more sensors would inevitably influence the cooling air duct, fewer sensors leaded to limited air information of the exhaust side for fewer samples.

Taking all the situations above into account, we finally set six lines, four measuring points each line. The sensor positions were arranged according to” Log-Tchebycheff”. The sketch map of array sensors assembly was shown in Fig.2.
Sensors could not be installed directly at the cooling air exhaust of engine compartment. We have studied a variety of schemes, finally, designed a frame according to the vehicle size as the bracket for array sensors. The frame, made of metal and with the shape of glyph in Chinese letter “Purpose”, was embedded at the outer edge of exhaust hood; two small bridges in the middle of the frame were firmly hooked to the shutters respectively by two hook-type metal firmware, in this way the metal frame was fixed at the exhaust side of engine compartment. There were six special mounted plates arranged on the metal frame. Four micro-pressure sensors were fixed on each mounted plate, and their corresponding air conditioning circuits were fixed into an aluminium sealed box at the end of each mounted plate for anti-electromagnetic interference and less measurement error. Then all the 24 micro-pressure sensors with the range of ± 6kPa were fixed to the position of the tank exhaust port shutter and every sensor inlet was just vertical to the shutter flat.

4. Data processing and analysis

4.1. Signal Processing of Tank Cooling Airflow

During the process of cooling airflow signals which we collected in the tank tests, basic low-pass filter was used as method one, however, energy of the filtered signal was much smaller than that of the original one, which means there was energy loss. We thought out a new signal processing method as method two, which was named as “residual energy method” [6].

The original signal, the processed results with two methods were placed together in one figure of the same scale for comparison, as shown in Fig.3. Some details of the signal were restored by method two, and there was a much better correspondence of the air pressure alteration and the cooling fan alteration, and of course there were better restored signals. The rationality and validity of the very signal processing method were verified [6].
4.2. The Fitting Analysis of the Measurement System

We have made many groups of tests for accurate, effective characters of tank cooling airflow. In this paper, several randomly selected sets of data were analyzed which were the data of tank with three different revolving speeds (speed 1 < speed 2 < speed 3) in time1 and time 2. Here time 1 was 1s in data acquisition time and time 2 was 2s. The 24 sets of signals of array sensors were processed by “residual energy method”, and then the processed data were linearly fitted according to the sensor positions and rectangular cross section of exhaust hood of engine compartment. The origin of coordinate system (0,0) for fitting was the left rear corner of tank, referring to Fig.2. X value increased to the right side of the vehicle and Y value increased to the front direction. The fitting results were presented simultaneously by three-dimensional surface graph and plane graph according to fitting algorithm, shown from Fig.4 to Fig.9.

Figure 3. Comparison of the original signal and the results of the two methods

Figure 4. Air pressure distribution of speed 1 in time 1(1s)
**Figure 5.** Air pressure distribution of speed 1 in time 2(2s)

**Figure 6.** Air pressure distribution of speed 2 in time 1(1s)
Figure 7. Air pressure distribution of speed 2 in time 2(2s)

Figure 8. Air pressure distribution of speed 3 in time 1(1s)
We could see from the results above that pressure values were roughly the same in one speed even at different acquisition time, so were the pressure distributions; at the same time point, the greater the speed, the higher the pressure value, and the pressures have different increases in different positions; but in general, despite of speeds and time, there was one thing in common from the graphs above, namely, the pressure values in regions of smaller Y were larger than that of other regions, just because the cooling fan was at the end inside the tank, when the fan operated, close to which there would be greater pressure.

5. Conclusion
According to the test requirements of tank under the actual working conditions, we studied and designed a feasible and reliable cooling airflow measurement system based on array sensors to cope with poor conditions like wide temperature range, electromagnetic interference, and inconvenient assembly. In this paper, there were description of cooling airflow signal processing and analysis of air pressure distribution in different speeds and different time by linear fitting algorithm. Nevertheless, we should keep trying to accomplish further theoretical deduction and algorithm implementation of heat and dissipation efficiency of engine compartment. These are the contents that need to be improved and supplemented later.

In a word, all the results show that we finished tank tests under the poor working conditions with cooling airflow measurement system based on array sensors, which is of great help to the measurement of tank parameters.

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