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Optimization of Heat Insulation Structure and Heat Flux Calculation Method of Slug Calorimeter

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Abstract : Heat flux is one of the most important test parameters in the ground thermal protection test. Slug calorimeter is selected as the main sensor measuring heat flux in arc wind tunnel test due to the convenience and low cost. However, because of excessive lateral heat transfer and the disadvantage of the calculation method, the heat flux measurement error of the slug calorimeter is large. In order to enhance measurement accuracy, the heat insulation structure and heat flux calculation method of slug calorimeter were improved. The heat transfer model of the slug calorimeter was built according to the energy conservation principle. Based on the heat transfer model, the insulating sleeve of the hollow structure was designed, which helped to greatly decrease lateral heat transfer. And the slug with insulating sleeve of hollow structure was encapsulated using a package shell. The improved insulation structure reduced heat loss and ensured that the heat transfer characteristics were almost the same when calibrated and tested. The heat flux calibration test was carried out in arc lamp system for heat flux sensor calibration, and the results show that test accuracy and precision of slug calorimeter are improved greatly. In the meantime, the simulation model of the slug calorimeter was built. The heat flux values in different temperature rise time periods were calculated by the simulation model. The results show that extracting the data of the temperature rise rate as soon as possible can result in a smaller heat flux calculation error. Then the different thermal contact resistance affecting calculation error was analyzed by the simulation model. The contact resistance between the slug and the insulating sleeve was identified as the main influencing factor. The direct comparison calibration correction method was proposed based on only heat flux calibration. The numerical calculation correction method was proposed based on the heat flux calibration and simulation model of slug calorimeter after the simulation model was solved by solving the contact resistance between the slug and the insulating sleeve. The simulation and test results show that two methods can greatly reduce the heat flux measurement error. Finally, the improved slug calorimeter was tested in the arc wind tunnel. And test results show that the repeatability accuracy of improved slug calorimeter is less than 3%. The deviation of measurement value from different slug calorimeters is less than 3% in the same fluid field. The deviation of measurement value between slug calorimeter and Gordon Gage is less than 4% in the same fluid field.

Keywords : correction method, heat flux calculation, heat insulation structure, heat transfer model, slug calorimeter
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