Applied Thermal and Fluid Engineering

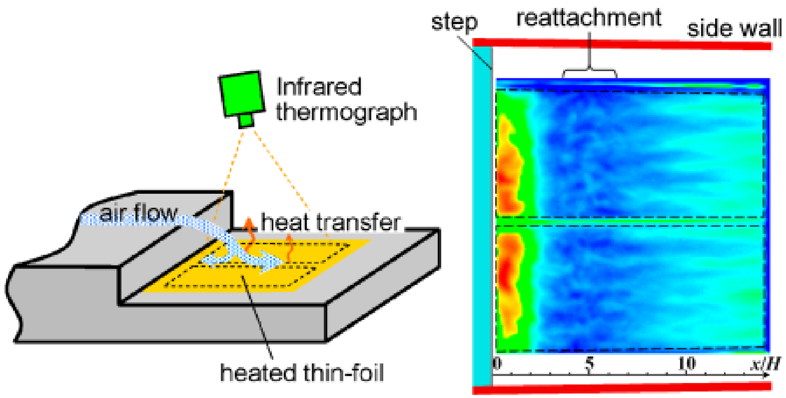
Energy Engineering
(Thermal Engineering Laboratory)

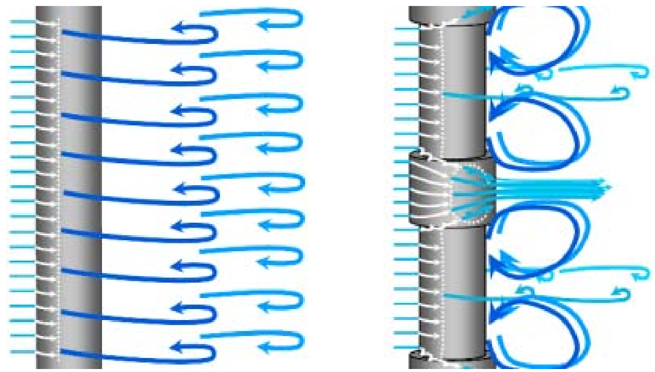
Professor	Hajime Nakamura
Assoc. Professor	Shunsuke Yamada

Outline of Research

In our laboratory, we have been conducting basic research mainly focused on convective heat transfer. In many cases, a fluid flow behaves very complex feature called “turbulence”. Therefore, the convective heat transfer actually fluctuates complicatedly in time and space, although not visible to the eye. We have experimentally investigated the spatial and temporal nature of the heat transfer in order to utilize the findings to improve the reliability of the thermal design and to improve the thermal efficiency of equipment.

Also, we have been investigated passive flow control of a cylinder by attaching axisymmetric protrusions in order to reduce the drag force and to suppress the fluctuating force caused by the vortex shedding.





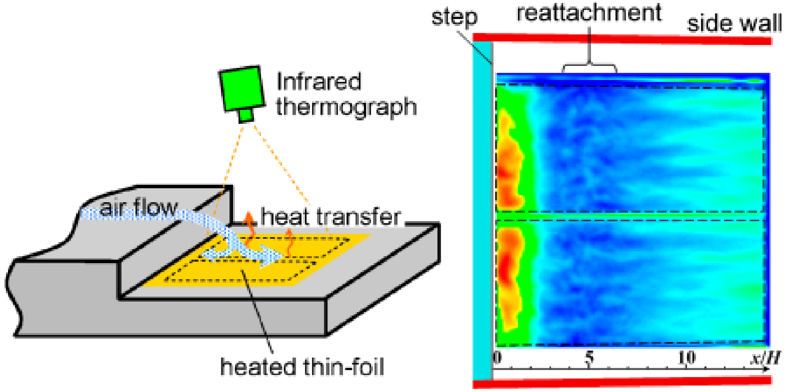
1. Unsteady heat transfer measurement using infrared thermograph

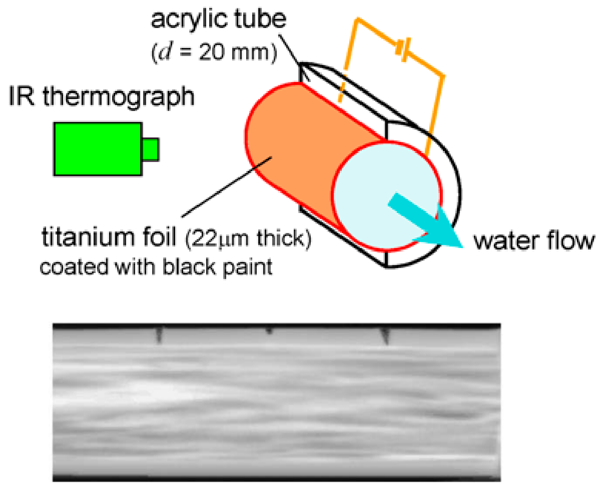
In our laboratory, we have developed a technique to measure unsteady convective heat transfer quantitatively using a high-speed infrared thermograph. Using this technique, we are now able to investigate the spatial-temporal behavior of the heat transfer visually as a movie, which have never been observed using point measurements such as thermocouples.

So far, we have performed (1) Derivation of analytical solution concerning the frequency-response and spatial-resolution of the measurement; (2) Design and experimental demonstration of the test model which can quantitatively measure the spatial-temporal variation of the heat transfer; (3) Measure the heat transfer to the airstream for a turbulent boundary layer and for separated and reattaching flows. As a result, it was demonstrated that the convective heat transfer actually fluctuates very complicatedly in time and space due to flow turbulence. Although the variation of the heat transfer appears to be a seemingly random, it was clarified to have some periodicity in the spatial distribution corresponding to such as the streak structure of the wall turbulence.

Recently, we have started to measure the instantaneous velocity distribution near the wall using PIV simultaneously with the heat transfer measurement in order to investigate the interaction between the turbulent vortical structure and the heat transfer. Also, we have started to measure the unsteady heat transfer to a water flow in a circular tube in order to acquire basic data for the thermal conjugation problems between fluid and solid.

(A part of this work was supported by JSPS KAKENHI Grant Number 22560214.)





thermo image of turbulent flow
(Re_d = 11700, playback speed 1/27)

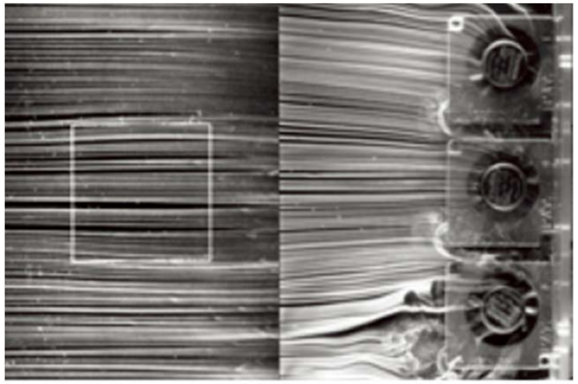
[main literature]

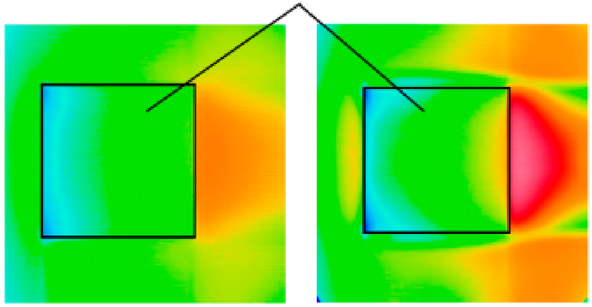
(1) Spatio-Temporal Measurement of Convective Heat Transfer Using Infrared Thermography, InTech open (2011)
http://www.intechopen.com/books/heat-transfer-theoretical-analysis-experimental-investigations-and-industrial-systems/spatio-temporal-measurement-of-convective-heat-transfer-using-infrared-thermography

(2) Frequency Response and Spatial Resolution of a Thin Foil for Heat Transfer Measurements Using Infrared Thermography, *Int. J. Heat and Mass Transfer*, **52** (2009), 5040-5045
http://dx.doi.org/10.1016/j.ijheatmasstransfer.2009.04.019

2. Studies on thermal design of electric equipment

According to the progress of high performance and miniaturization of electronic devices, the heat density of the devices continues to increase. Thus, it has been becoming an important issue how cooling the devices. In our laboratory, we conducted basic studies on heat transfer from an air-cooled heating element placed in an enclosure, which simulates a compact electronic device. Also, in order to simplify the thermal design for the air-cooled device using CFD, the fan-curve model was improved to reproduce the realistic flow field at the discharge side of a fan with a small computational load.
(A part of this work was conducted as a part of the RC181, 202, 214, 227, 239, 248 Research Projects, Japan Society of Mechanical Engineers.)


smoke visualization



thermo images

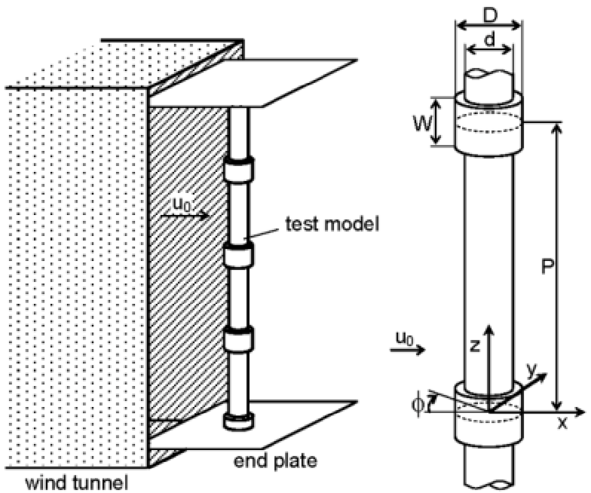
[main literature]

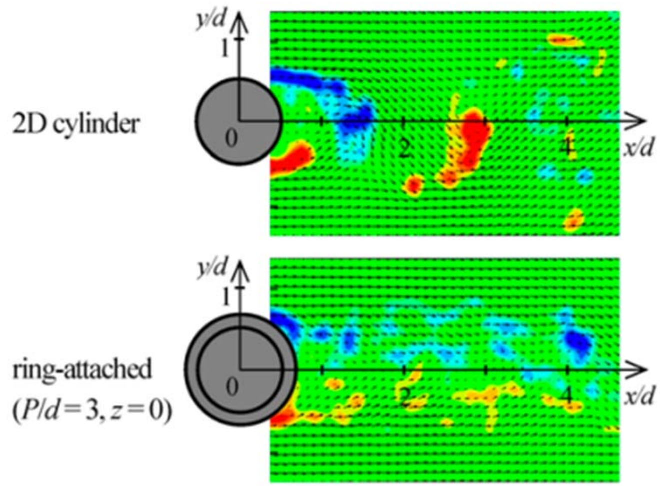
(1) Heat Transfer Enhancement of a Low-Profile Block in a Channel Flow at Low Air-Velocity, *Trans. Jpn. Soc. Mech. Eng.*, **71**-702 B (2005), 581-589 (in Japanese)
https://www.jstage.jst.go.jp/article/kikaib1979/71/702/71_702_581/_article

(2) Reduction in Flow Rate of Small Cooling Fans by an Obstruction, *Trans. Jpn. Soc. Mech. Eng.*, **76**-768 B (2010), 1184-1190 (in Japanese)
http://ci.nii.ac.jp/naid/110007682135/en/

3. Vortex shedding suppression from a cylinder

If a fluid flows across a cylindrical object, the periodic vortex shedding (Karman vortex street formation) occurs and causes large drag and fluctuating force. At the same time, it generates the aerodynamic noise, called Aeolian tone. In our laboratory, we have studied the method to suppress the vortex shedding by attaching axisymmetric projections, named “rings”, arranged in the axial direction of the cylinder. Since the ring-attached cylinder is axially symmetry, the vortex shedding can be suppressed with respect to the flow in all directions perpendicular to the cylinder. Experimental results showed that the periodicity in the fluctuating lift is almost disappeared with a reduction of the drag for the Reynolds number higher than 20,000 if the configuration of rings was optimized. We have conducted measurements of the wake and flow visualization in order to clarify this mechanism.





[main literature]

(1) Reductions in Drag and Fluctuating Forces for a Circular Cylinder by Attaching Cylindrical Rings, J. Fluid Science and Technology, **2**-1 (2007), 12-22
http://dx.doi.org/10.1299/jfst.2.12

(2) Suppression of Fluctuating Lift on a Circular Cylinder by Attaching Cylindrical Rings, J. Fluid Science and Technology, **6**-6 (2011), 1036-1050
http://dx.doi.org/10.1299/jfst.6.1036

4. Forced convection heat transfer around an object

We have measured the local heat transfer distribution around an object with a basic shape, such as a circular cylinder and a wall-mounted cube, and have examined the correspondence between the flow field and the heat transfer. The data obtained in these experiments can be used for thermal design of equipment, and also be used to validate CFD model.

[main literature]

(1) Local Heat Transfer around a Wall-Mounted Cube in the Turbulent Boundary Layer, *Int. J. Heat and Mass Transfer*, **44**-18 (2001), 3385-3395
http://dx.doi.org/10.1016/S0017-9310(01)00009-6

(2) Local Heat Transfer around a Wall-Mounted Cube at 45 Degree to the Flow in the Turbulent Boundary Layer, *Int. J. Heat and Fluid Flow*, **24**-6 (2003), 807-815
http://dx.doi.org/10.1016/S0142-727X(03)00087-0

(3) Heat Transfer in Separated Flow Behind a Circular Cylinder for Reynolds Numbers from 120 to 30000 (2nd Report, Unsteady and Three-Dimensional Characteristics), *JSME Int. J., Ser.B*, **47**-3 (2004), 622-630
http://dx.doi.org/10.1299/jsmeb.47.622

(4) Unsteady Heat Transfer from a Circular Cylinder for Reynolds Numbers from 3000 to 15,000, *Int. J. Heat and Fluid Flow*, **25**-5 (2004), 741-748
http://dx.doi.org/10.1016/j.ijheatfluidflow.2004.05.012

(5) Variation of Nusselt Number with Flow Regimes Behind a Circular Cylinder for Reynolds Numbers from 70 to 30000, *Int. J. Heat and Mass Transfer*, **47**-23 (2004), 5169-5173
http://dx.doi.org/10.1016/j.ijheatmasstransfer.2004.05.034