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Heat transfer coefficient measuring method at the inside wall of an agitated vessel

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ABSTRACT

A new method to measure the surface temperature on the wall of an agitated vessel is presented for estimating the heat transfer coefficient at the wall in the mixing high Re region. The device consists of the thin type thermo couple and super-point thermo couple and they are coated with solder on the surface of the wall.

The reliability of this method is confirmed by experiments which use the model water tank imitated an agitated vessel and the test piece (thickness 10, 20 mm) imitated the wall of an agitated vessel. The temperature obtained by this new method is compared with the temperature which is extrapolated from the data of the three thermo couples (I.D 0.25 mm) inserted in the wall of the model water tank.

There are two typical conventional methods. One of traditional methods is to estimate the surface temperature by extrapolating from the date of two thermo couples in the wall. The other one is the method by setting a thermo couple in a channel trenched on the wall surface. Comparing these traditional methods, the newly presented method is more simply and more precise than the conventional methods. Therefore, it is expected that this newly presented method will become an effective measure for the design of mixing device from now on.

INTRODUCTION

The heat transfer operation on the mixing device has various roles, the main roles are the following 1~4.

1. Heat elimination on the chemical reaction.
2. Fluid temperature control on the crystallization.
3. Fluid temperature rising on the dissolution process.
4. Others.

Usually, heat transfer performance indexes are used as follows

1. Overall heat transfer coefficient : U
2. Heat transfer coefficient at vessel wall : h
   (between the fluid and the vessel wall)

The occurrence problems on the heat transfer operation by the mixing device are that the decline or change of the product's quality, the adhesion on the surface of the vessel wall and the others. For resolving these problems, it is necessary to make clear the heat transfer coefficient distribution at the vessel wall.

The key point for making clear the heat transfer coefficient distribution at the vessel wall is the precise measuring method of the temperature slope in the vessel wall.

This study presents the new method to measure the temperature slope in the vessel wall.

EXPERIMENTAL METHODS AND DEVICES

Experimental Devices

Experimental devices are shown in the schematic figures of Figs.1~3. Fig.1-1 is the side view of the model tank. Fig.1-2 is the upper view of the model tank. The model tank width, depth, height is 120(mm), 80, 80, respectively. Also this tank is made of transparent acrylic resin in order to observe flow pattern in the model tank. The fluid is used water and Water is poured continuously to hold the steady condition of the water temperature (about 25~40 ^{0}C). Steam is injected in the injecting pipe at 0.05MpaG (about 110~112 ^{0}C).Flow pattern of the model tank is presented by two types that are shown in Fig.1-2.One is the jet flow which is reproduced the pumping flow strike on the vessel wall. The other is the parallel flow which is reproduced the rising flow at vicinity to the vessel wall. The left side figure shows the jet flow and the right side figure shows the parallel flow respectively in Fig.4.

Fig.2 shows the test piece slotting the model tank (Fig.1). The test piece width, depth and height are 80mm. The thickness is 5(mm), 10, 20. Also the material is stainless steel which is the same as the vessel wall.

Fig.3 shows the thermo couples which are attached to the surface of the test piece. The thermo couples are 2-types, One is the superfine-pointed coating type on the steam side and the other is the thin type on the water tank side. The superfine-pointed coating type diameter is 0.5mm.The thin type width, depth is 5mm, 3.2 respectively and the thickness is 40μm. Besides the thermo couples inserted in the test piece are the "Ultra Fine thermo couples Mineral Insulated" of which the diameter is 0.25mm in Fig1-1.
The type of all the thermo couples are K type.

Experimental Methods

The experimental contents are the following 1~3.

1. Confirm that the temperature slope at the three points of the test piece is obtained a straight line.
2. Verify the thermo couple's setting method on the test piece.
3. Confirm that the new method is corresponding with the extrapolation by using the test piece of which the thickness is the same as the agitated vessel wall.

The extrapolated method and the new method show in Fig.5. The extrapolated method is obtained at the surface temperature of the test piece by using the temperature slop of which two or three thermo couples in the test piece to obained the temperature.

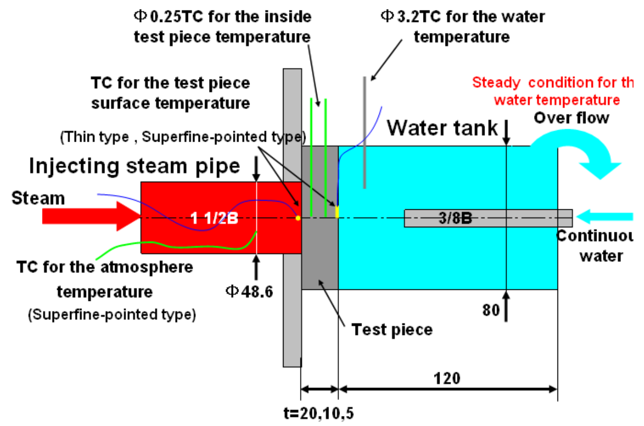


Fig. 1-1 Model Tank (Side view)

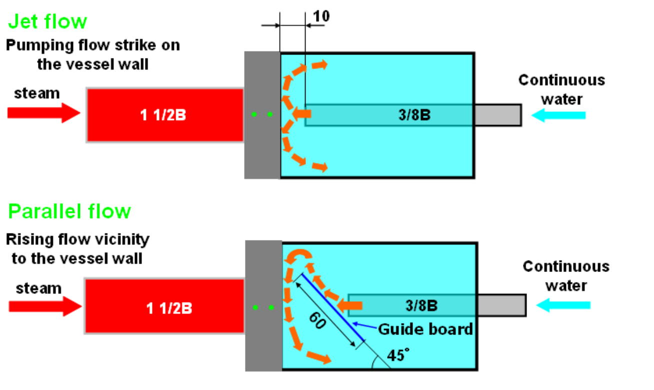


Fig. 1-2 Model Tank (Upper view)

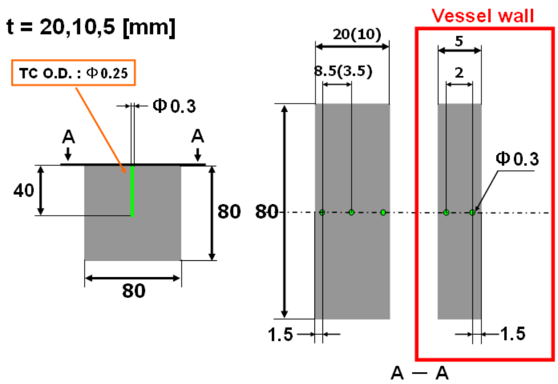


Fig. 2 Test Pieces

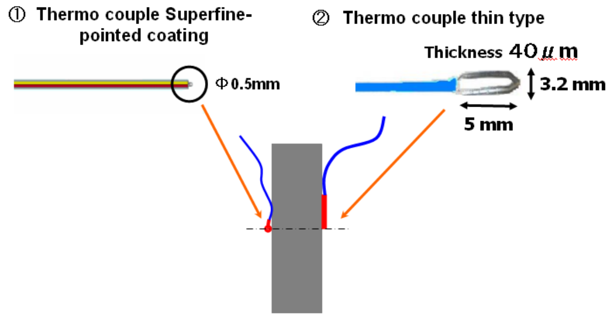


Fig. 3 2-types of Thermo Couples

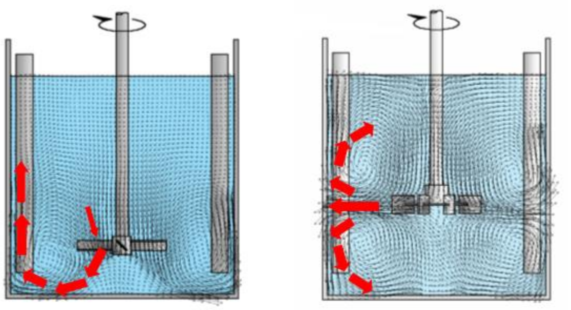


Fig. 4 Flow pattern

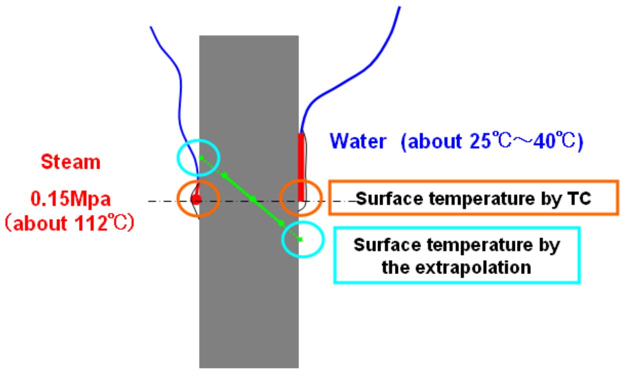


Fig. 5 The new method and the extrapolation

EXPERIMENTAL RESULTS AND DISCUSSIONS

1. Confirmation of the temperature slope

In Fig.5, the left figure shows the temperature slop of the jet flow and the right figure shows the temperature slope of the parallel flow. The thickness of the test piece is t=20mm.

$$q = \frac{\lambda}{t} \times \Delta T \qquad (1)$$

$$E1 = (q_{Large} - q_{Small}) / q_{Large} \times 100 \qquad (2)$$

Eq. (1) shows the heat flux and Eq. (2) shows the error between q which is obtained by measuring at two points from the steam side and two points from the water side.

It is confirmed that the temperature slope of these three points on the test piece showed a straight line in the both flow pattern. A similar tendency is also obtained for t=10mm. Therefore, it was confirmed that a precise surface temperature of the test piece is obtained by using this method.

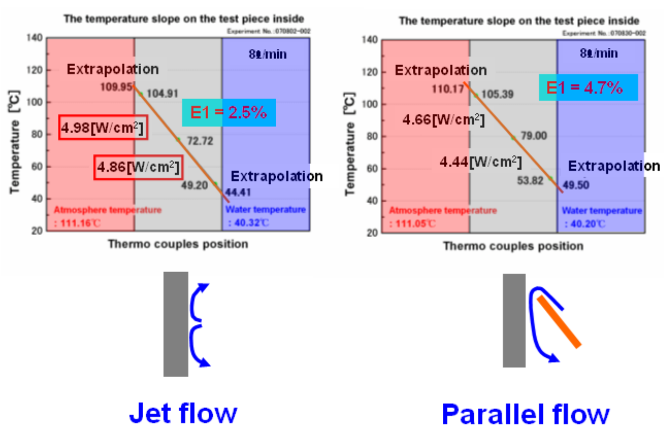


Fig. 5 The temperature slop at t=20(mm)

2. Verification of the thermo couple's setting method

The setting methods are applied the following 1~4.on the water side.

1. Polyimide film tape
2. Silver paste
3. Solder
4. Others

These methods differ from the thermal conductivity of the material of which a thermo couple is attached on the test piece. Table 1 shows the thermal conductivity of the material

Table 1 The thermal conductivity of the material

Material type	Thermal conductivity [W/m・K]	
Stainless steel	15	
Polyimide film tape	0.8	
Silver paste(Ag about 65%)	over 7.5	
Solder(50Sn)	49	
Satuma paste	about 9～15	
Alumel(2Al 2Mg 1Si)	29.7	Thermo couple
Chromel(80Ni 20Cr)	13.8	

※ Silver paste and Satuma paste include the epoxy resin

In Fig.6~.8 the left figure shows the temperature slop of the jet flow and the right figure shows the temperature slope of the parallel flow by using Polyimide film, Silver paste, Solder, respectively.

It was confirmed that the error of the "Solder method" is approximates to the extrapolated method. A similar tendency is also obtained for t=10mm.Therefore, the setting method is adopted the "Solder method".

3. Confirmation of the new method

3- 1 . The water side

It is verified whether the new method is corresponds to the extrapolated method by using the test piece of which the thickness is the same as the agitated vessel wall on the water side. The feed rates of the water is altered to 2, 4, 6, and 8 l/min in order to reproduce the alteration of the velocity in the agitated vessel. Fig.9 and 10 show the comparison between the measured and the extrapolation of the jet flow and parallel flow, respectively, on the water side. Eq. (3) shows the error between the extrapolated method and the new method.

$$E2 = (T_{Large} - T_{Small}) / T_{Large} \times 100 \quad (3)$$

In the both cases it was confirmed that the new method corresponds sufficiently to the extrapolated method in all alterations of the water and the errors are within about 2%.

Fig.11 shows the big error result's samples. This results indicated that if the thermo couples attaching by the solder method are not polished up by its surface, the errors are over about 2%. Therefore, the thermo couple which is soldered on the vessel wall must be polished up by its surface.

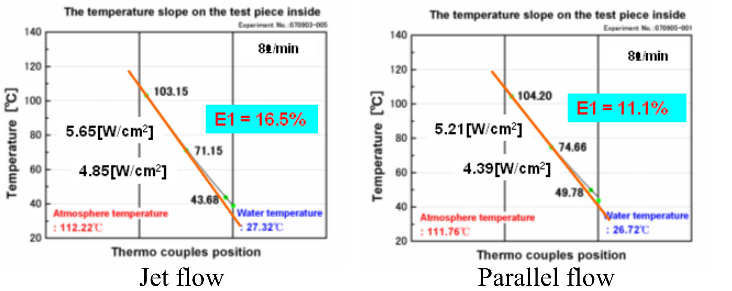
3-2. The steam side

It is verified by the following 1 and 2. by using the test piece of which the thickness is the same as the agitated vessel wall on the water side. The feed rates of the water are altered to 2, 4, 6, and 8(l/min) in order to reproduce the alteration of the velocity in the agitated vessel.

1. Thermo couple's type
2. The new method is corresponding with the extrapolated method.

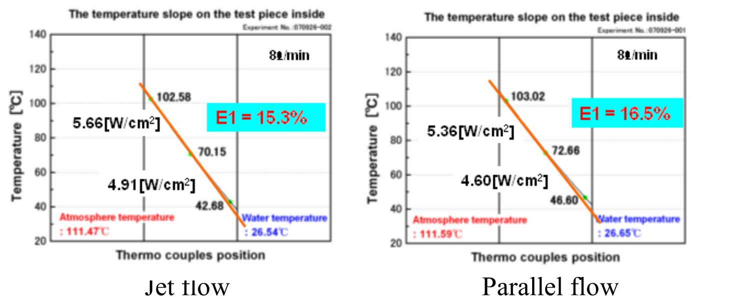
3-2-1. Thermo couple's type

It is verified that which one is suitable; the thin type or the superfine-pointed coating type.



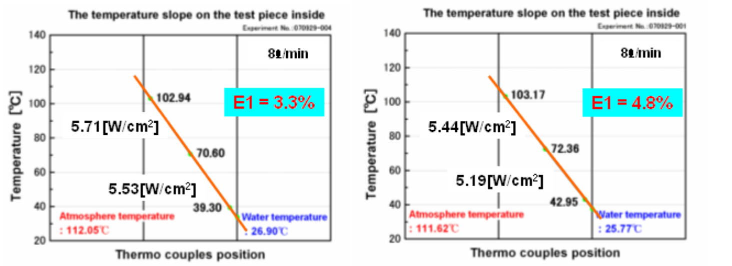
Jet flow Parallel flow

Fig.6 The temperature slope by Polyimide film at t=20(mm)



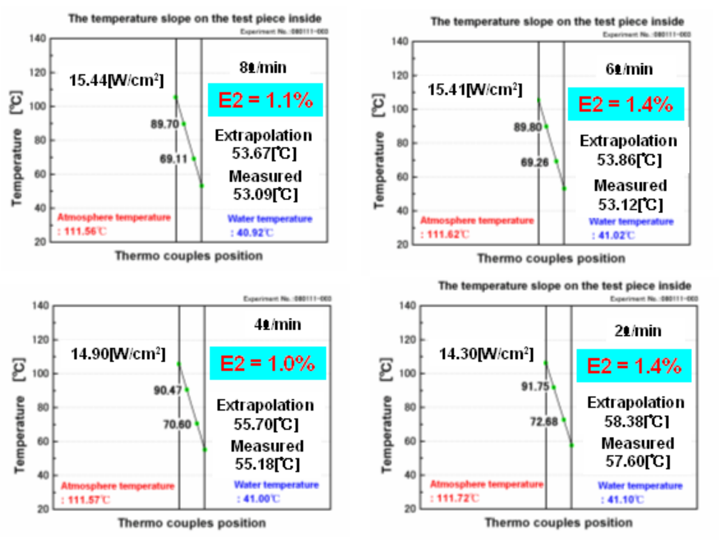
Jet flow Parallel flow

Fig.7 The temperature slope by Silver paste at t=20(mm)



Jet flow Parallel flow

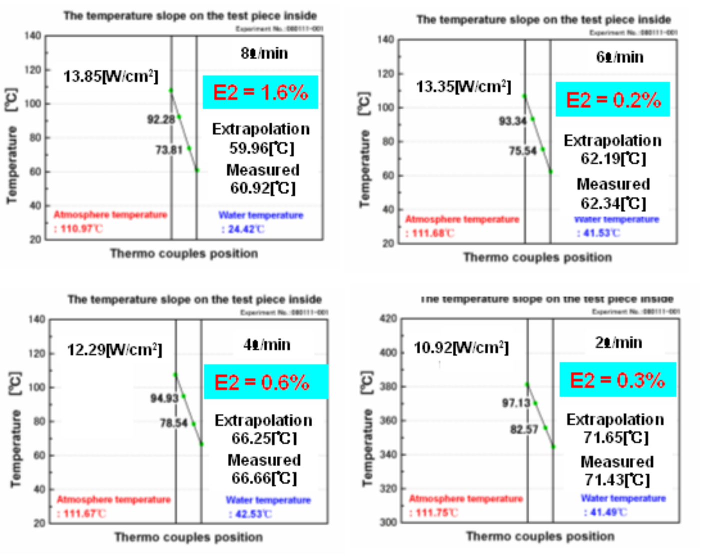
Fig.8 The temperature slope by Solder at t=20(mm)



Jet flow

Fig.9 Comparison between the measured and the extrapolation at the jet flow

Fig.12 shows the comparison between the measured and the extrapolation by using the thin type and Fig.13 show the comparison between the measured and the extrapolation by using the superfine-pointed coating type.



Parallel flow

Fig.10 Comparison between the measured and the extrapolated results at the parallel flow

It is confirmed that the errors of the superfine-pointed coating type are within about 2% at the jet flow and the parallel flow. Therefore, the superfine-pointed coating type of the thermo couple is adopted on the steam side.

3-2-2. Confirmation of the new method

It is verified whether the new method corresponds to the extrapolated method by using the test piece of which the thickness is the same as the agitated vessel wall on the steam side. The feed rates of the water are altered to 2, 4, 6 and 8 l/min in order to reproduce the alteration of the velocity in the agitated vessel.Fig.14 and 15 show the comparison between the measured value and the extrapolated value at the jet flow and parallel flow, respectively, on the steam side. The equation of the error is similar with the water side.

In the both cases, it was confirmed that the new method is corresponds sufficiently to the extrapolated method in all the alterations of the water feed rate and the errors are within about 1%.

CONCLUSIONS

The new heat transfer coefficient measuring method at the vessel wall is presented and it is made clear that the method can replace old one by experiments.

UNITSAND SYMBOLS

q	=	heat flux in the test piece	[W/cm^2]
λ	=	thermal conductivity	[W/mK]
t	=	thickness of the test piece	[mm]
T	=	temperature	[^{0}C]
ΔT	=	temperature difference	[^{0}C]
E1	=	error	[%]
E2	=	error	[%]

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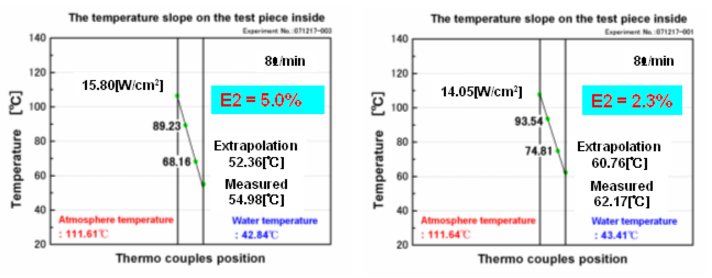
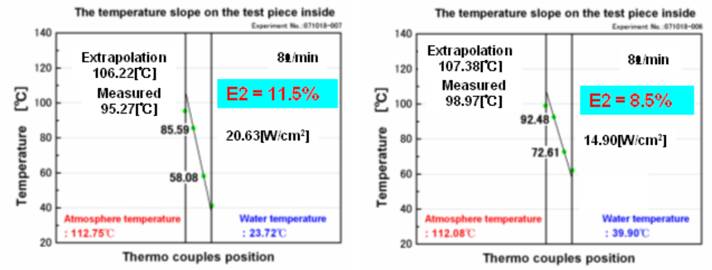


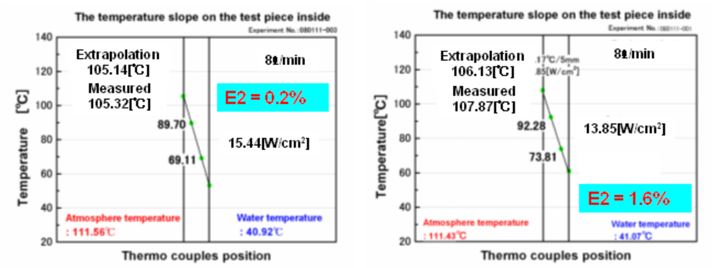
Jet flow Parallel flow

Fig.11 Example of the big error result's



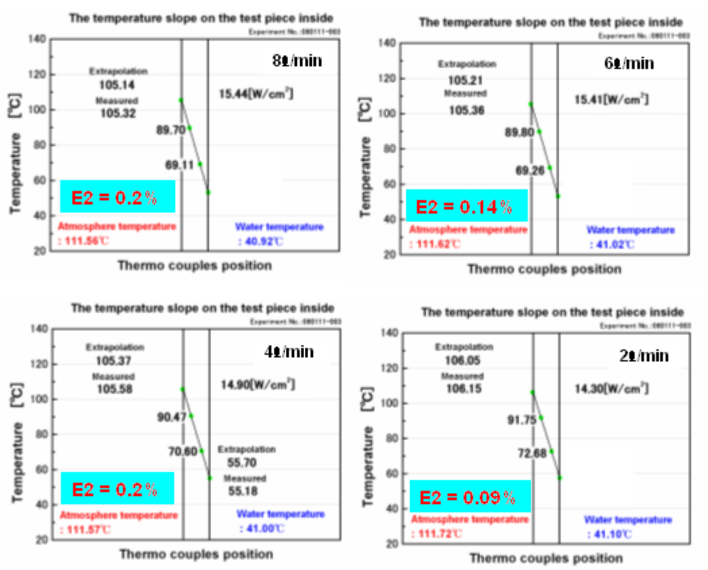
Jet flow Parallel flow

Fig.12 Comparison between the measured and the extrapolated results in the case of the thin type



Jet flow Parallel flow

Fig.13 Comparison between the measured and the extrapolated results in the case of the superfine-pointed coating type



Jet flow

Fig.14 Comparison between the measured and the extrapolated results at the jet flow

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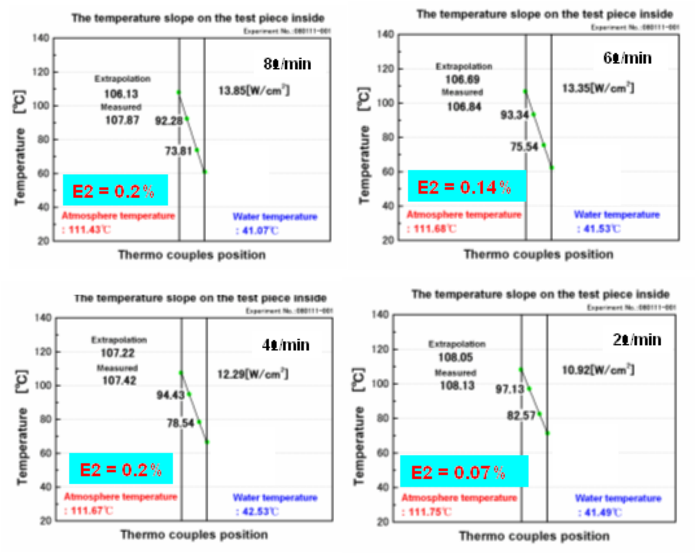

Parallel flow
Fig.15 Comparison between the measured and the extrapolated results at the jet flow