Journal of POLISH CIMAC
Faculty of Ocean Engineering & Ship Technology
GDAŃSK UNIVERSITY OF TECHNOLOGY

THE RESEARCH OF THE INFLUENCE OF THE CYLIDRICAL HEATING SURFACE LOCATION ON THE LOCAL HEAT TRANSFER COEFFICIENTS IN FLUIDISED BED OF THE MARINE FLUIDISED BED BOILER

Wojciech Zeńczak

West Pomeranian University of Technology in Szczecin
41 Piastów Ave, PL 71-065 Szczecin, Poland
tel.: +48 91 4494431, fax: +48 91 449 4737
e-mail: wojciech.zenczak@zut.edu.pl

Abstract

The article presents the results of the experimental research of the heating cylindrical surface location influence on the local heat transfer coefficients in the bubbling fluidised bed in the physical model of the marine fluidised bed boiler. A particular feature of this boiler model is positioning it in a kind of cradle simulating ship's motion on sinusoidal type regular wave. The heating surface is located in the traditional ship's centre line or in her midship section. The testing has been conducted in the conditions where the fluidising column remained motionless while being at the same time deflected from the vertical by a constant angle and in the conditions of continuous oscillating movement. In the effect there has been obtained the distribution of the heat transfer local coefficient values in the fluidised bed in three points located at the diameter of the column at a certain distance from the separating grid with various locations of the heating surface. The research has indicated that column oscillations contribute to the increase of the bubbling fluidised bed local heat transfer coefficients, at the parallel positioning towards ship's centre line. The further results of research may provide the grounds to formulate guidelines for designing the shipboard fluidised bed boilers.

Keywords: *heat exchange, fluidised bed boiler, design, ship*

1. Introduction

While designing the marine steam boilers, certain rules due to ship's rolling motion on waves should be observed in order to make the boiler operation safer and the risk if its damage gets less. In case of water-tube boilers with natural circulation such rule is for instance positioning of boiler drums in such a manner that their axis of symmetry is parallel to ship's centre line. On the other hand, their positioning with the axis in perpendicular to ship's centre line would cause excessive fluctuations of water level while rolling thus threatening the proper and safe boiler operation.

Whereas in case of forced circulation boiler heating surfaces, e.g. evaporator or superheater consisting of pipe bunches, their location towards the ship's centre line becomes less significant. There are arrangements encountered involving pipe positioning both rectangular and in parallel to this line. The ship's side rolling has no such significant impact in this case onto the pump-forced working medium flow. Also in connection with exhaust gas flow in view of its strong turbulent motion and its minor inertia, the ship's rolling motion practically does not affect the performance of the said heat exchangers.

On the other hand the situation changes completely if we consider the heating surface immersed in the bubbling fluidised bed formed by grains of fuel and inert material suspended in the stream of flowing air. Such is the case with fluidised bed boilers. Under the influence of ship's rolling such bubbling bed behaves similar to liquids. Also the movement of grains in the bed itself changes which influences the local coefficients of heat transfer in the bed [5]. In this situation it is interesting to investigate the influence of the positioning of heating surface on the values of the local coefficients of heat transfer within the bed.

2. The Course of the Research

In order to find the answer to the question asked in the introduction several experiments have been conducted on the test stand specified in detail in [2]. The same method of determination of the local coefficients of heat transfer has been applied as referred to in the studies [5, 2]. The equivalent to a pipe in boiler bunch is here a cylindrical heating element (copper pipe) with electric spiral placed inside. The scope of research has required conducting of series of measurements for two various pipe positions, i.e. while the pipe axis is situated in parallel to midship section, and then when the pipe axis is situated in parallel to ship's centre line. In the present construction of the stand the pipe can only be positioned in such a manner that its axis remains perpendicular to the column axis. This restriction results from the circular column cross-section. In the future it is planned to apply new version of the stand with the column of square cross-section which will allow to locate the pipe along the side walls of the column. The diagram of both positions of the pipe, distribution of thermocouples and the directions of movement of fluidising column are shown in Fig. 1, and the Fig. 2 demonstrates the view of a stand part.

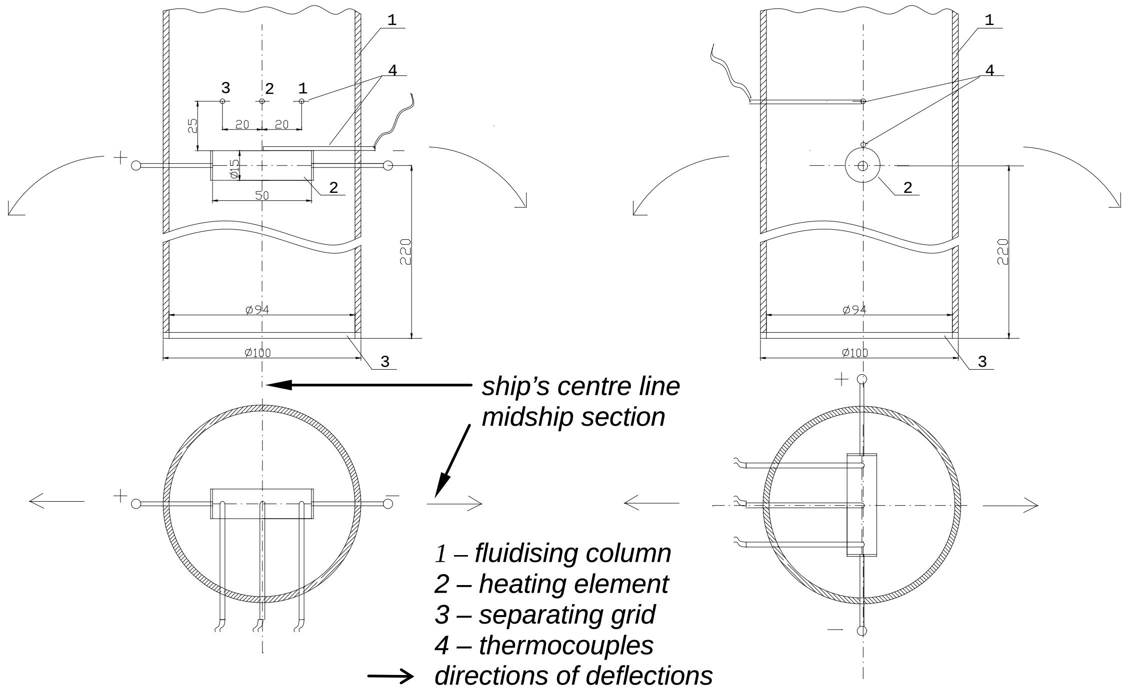

Fig. 1. Diagrams of the positioning of heating element and distribution of thermocouples

3. The Results of the Research and their Analysis

At the stand in question there have been previously tested the local heat transfer coefficients in the bed involving one permanent positioning of heating pipe, i.e. in parallel to midship section, whereas the bed height in rest condition and number of fluidisations have been changed. The influence of column deflection from vertical has been also investigated with regards to the values of the local heat transfer coefficients. A major conclusion from this investigation has been the statement that the column deflection from vertical results in reduction of mean values of heat transfer coefficients, while the reduction tended to grow at the side towards which the deflection occurred. The results of these investigations have been presented inter alia in [5].

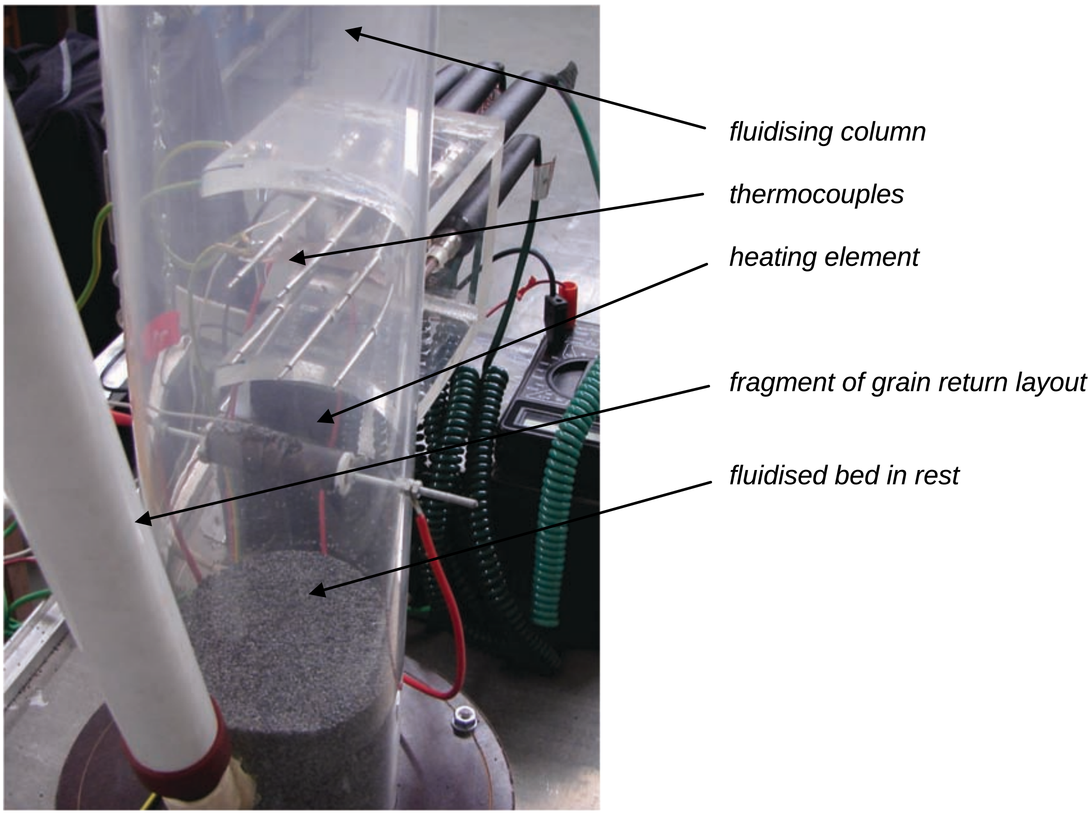

Fig. 2. View of the stand

The first test upon the change of heater positioning to that in parallel to ship's centre line has been the checking of the influence of the number of fluidisations on the values of heat transfer coefficients in the bubbling fluidised bed. The examinations have been conducted for the permanent bed height in rest, i.e. 0.12 m. The bed material, similar like in the former testing, have been the poppy seeds. The heater power has been kept at the constant level of 45 W. According to the suppositions, in view of full symmetry of the system, in the column vertical position, the nature of the changes of heat transfer coefficients has remained the same as in the positioning referred to above – heater parallel to midship section. As the fluidising air velocities grow, also the heat transfer coefficients grow as well. Their distribution along the radius R of the column for the velocities 2.6 m/s and 4.5 m/s at the distance of 0.245 m over the separating grid in points separated by the value r from the column axis is presented in Fig. 3.

As can be observed from the course of the curves, the values of the local coefficients of heat transfer are somewhat smaller closer to the walls on account of the circulation occurring inside the bed caused by well entry loss.

The subsequent measurement series have been conducted for the column inclined by permanent angle of 22 ° to the left, and then inclined permanently by the angle of 28 ° to the right. The investigation has been conducted for the fluidising air velocity of 4.5 m/s. The results are presented in Fig. 4. They indicate the symmetry of the distribution of the coefficient value of heat transfer regardless from the direction of column inclination (V – vertical, L – left, R – right). Thus in this case the characteristic reduction of coefficient values at the inclination direction does not occur. On the other hand there can be noticed general reduction of all coefficient values at the column inclination. The bigger decrease of the values can be observed at a bigger inclination , in this case for the inclination towards the right (alpha 4.5-R). But a slight reduction of the coefficient values in each case at the right side of the column results from the constant difference in the indications by thermocouples 1 and 3 (Fig. 1).

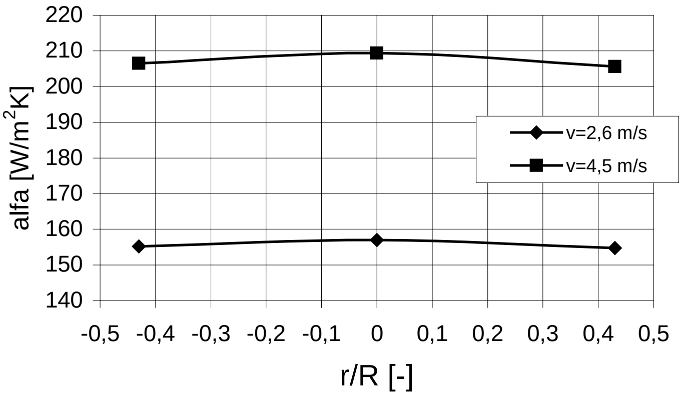

Fig. 3. The values of the local coefficients of heat transfer along the line at a distance of 0.245 m over the separating grid with the column in vertical position

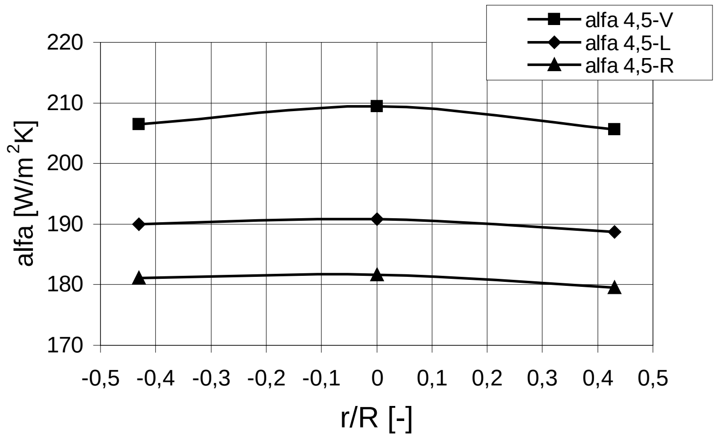

Fig. 4. The values of the local coefficients of heat transfer along the line at a distance of 0.245 m over the separating grid with the column vertical position (V), inclinations to the right (R) and to the left (L)

Fig. 5 presents the diagrams showing the distribution of the values of the local heat transfer coefficients for the same fluidising air velocity of 2.4 m/s with two different heater positions, i.e. in parallel to ship's centre line (alfa 2,4–R longitudinally) and rectangular to it (alfa 2,4-R transversely) in another manner, in parallel to midship section, with column permanently inclined to the right. To make the comparison better there is also presented a diagram showing the distribution of the values of local heat transfer coefficients with the column positioned vertically (alfa 2,4 V). As already mentioned with the vertical column positioning the heater orientation is of no consequence.

The same measurements have been repeated for the column inclined to the left with the same fluidising air velocity, i.e. 2.4 m/s. Fig. 6 presents the results in the form of diagrams. The line marked as "alfa2,4–L longitudinally" shows the distribution of the values of heat transfer coefficients with heater positioned in parallel to ship's centre line, whereas the line marked as " alfa2,4 – L transversely" with the positioning rectangular to this centre line. Similar as in Fig. 5 also here a diagram is presented to show the distribution of the local values of heat transfer coefficients with column vertical positioning (alfa 2.4 V).

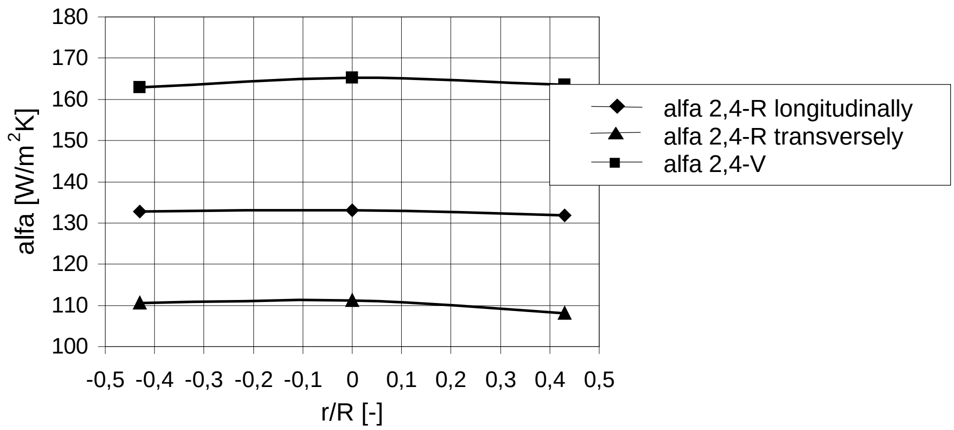

Fig. 5. The values of the local coefficients of heat transfer along the line at a distance of 0.245 m over the separating grid with the column vertical position (V) and column permanently inclined to the right (R) and heater transverse and longitudinal positioning in relation midship section

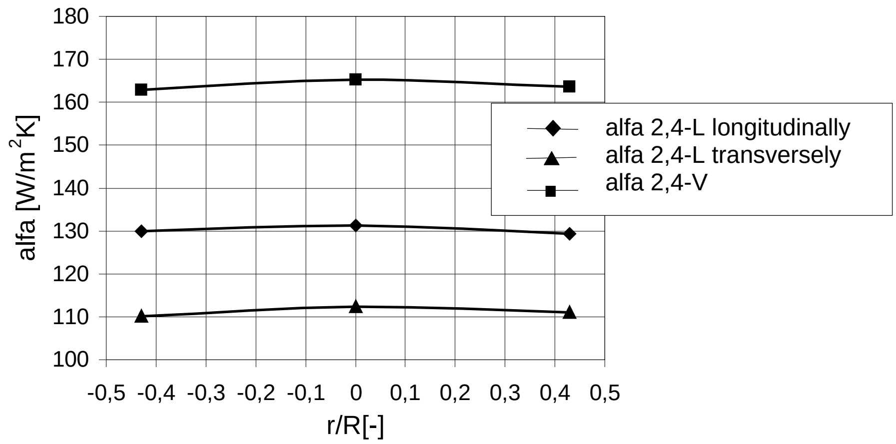

Fig. 6. The values of the local coefficients of heat transfer along the line at a distance of 0.245 m over the separating grid with the column vertical position (V) and column permanently inclined to the left (L) and heater positioned longitudinally or transversely in relation to ship's centre line

As visible in figures 5 and 6, in case the heater is positioned transversely to the ship's centre line, there can be observed previously mentioned typical reduction of the value of the local heat transfer coefficient at the side to which the inclination has occurred. However, the most meaningful conclusion is that with the heater positioned transversely the mean values of the local heat transfer coefficient, regardless of the column inclination direction, along through the line of the heater are less than the values of the coefficients along the heater while it is positioned longitudinally to ship's centre line.

In the maritime practice the conditions when a vessel sails with a permanent major list to one side are quite rare. More complex ship's movements on the waves are however general. In many shipbuilding issues, however, it is sufficient to take into account only so called simple rolling, i.e. of one degree of freedom, occurring only in ship's centre line or midship section. Such approach is most frequently related to ship's rolling movements which on the their intensity due to direct relation with the stability safety and also the effectiveness of the performance of some systems and operations are of special significance [3]. Simple rolling without being combined with any other movements is however a little too far fetched approximation of actual conditions, but still acceptable in the research of the behaviour of the fluidised bed in these conditions which is proven also in other research studies, e.g. [4].

The stand where the aforesaid testing has been made allows to conduct the examination of the average values of the local coefficients of heat transfer during the constant oscillating movement approximating just the ship's rolling on a regular wave of sinusoidal type. It is also assumed that the vessel is on even keel.

The examinations have been conducted for the transverse and longitudinal heater positioning with constant oscillating movement of 28 s period and inclinations of 22 ° to each side. The figure 7 shows the results in the form of diagrams. The line marked as "alfa L–R longitudinally" shows the distribution of the values of heat transfer with heater positioned in parallel to ship's centre line during pendular motion, whereas the line marked as "alfa L–R transversely" with its positioning rectangular to this line also during pendular motion.

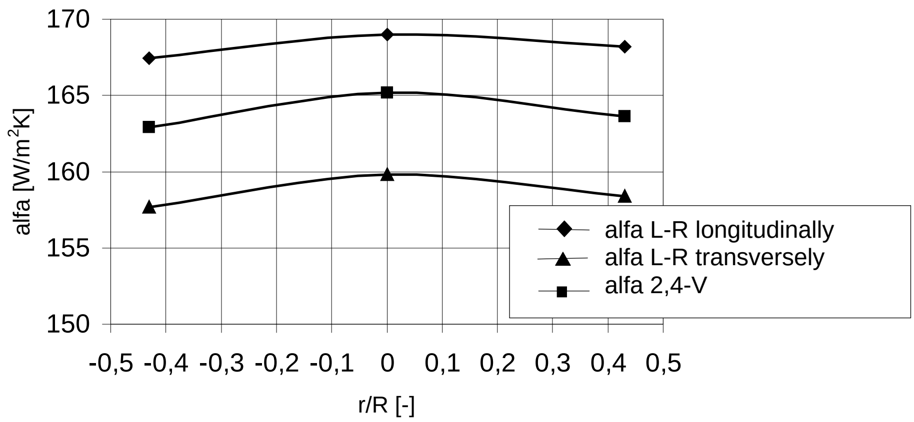

Fig. 7. The values of the local heat transfer coefficients along the line at a distance of 0.245 m over the separating grid with the column positioned vertically (V) and during column pendular movements with transverse or longitudinal heater positioning in relation to ship's centre line

For the sake of comparison also diagram is presented that shows the distribution of the values of the local heat transfer coefficients with permanent motionless vertical column positioning and air velocity of 2.4 m/s (alfa 2,4–V). During the column oscillating motion the fluidising air velocity has changed by itself within 2.4 up to 3.2 m/s. The velocity fluctuations are caused by the varying resistance characteristics of the fluidised bed during inclinations. The fluidised bed location out of parallel in relation to the separating grid during inclinations causes the drop in flow resistance and faster transfer into fluidised state, as well as increase in air velocity. These issues have been discussed more in detail in the study [1].

As can be observed from the courses in the diagrams the smallest average values of the local heat transfer coefficients along the line at a distance of 0.245 m above the separating grid occur during oscillation with the transverse heater positioning towards ship's centre line. They are however bigger than with the constant list to port or starboard, in such heater positioning with the fluidising air velocity of 2.4 m/s (figures 5 and 6). The biggest values of the local heat transfer coefficients are reached with the longitudinal heater positioning and during column oscillation (alfa L–R longitudinally). Therefore the conclusion can be drawn that the column oscillations contribute to the increase of the local heat transfer coefficients, with parallel heater positioning in relation to ship's centre line, in comparison to the values of the coefficients obtained in motionless column positioned vertically (alfa 2.4-V). Another reason of such result are the local changes in the material concentration within heater area.

4. Conclusions

On the basis of the presented research results it can be concluded that the manner of heater positioning in relation to ship's centre line does influence the average values of the local coefficients of heat transfer with permanent list or in continuous oscillating movement. In the examined positions the arrangement with the heater in ship's centre line has proven better.

On the basis of the results obtained, however, it cannot be unambiguously stated that in the construction of marine fluidised bed boilers – on account of heat exchange conditions – there should be preferred the longitudinal positioning of the pipes of heat exchangers immersed in bed in relation to ship's centre line. It is necessary to complete the examination of the heat transfer coefficients with the heater also positioned in parallel planes to ship's centre line and the examined midship section with the application of fluidising column of square cross-section.

The conclusions from the above investigations, conducted with the use of certain simplifications, give the grounds to continue experimenting with the application of more advanced simulators of ship's full movement on irregular wave. It also seems worthwhile to extend the scope of research by the inclusion of circulating fluidised bed.

References

[1] Adamkiewicz, A., Zeńczak, W., *Model Testing of Fluidised Bed Boiler for Sea-Going Ships*, Marine Technology Transactions, Vol.17 , Gdańsk 2006, pp.23-35.

[2] Adamkiewicz, A., Zeńczak, W., *Koncepcja badań modelowych kotłów fluidalnych w aspekcie możliwości ich zastosowania na statkach morskich*, Systems, 2006, Vol.11, Special Issue 1/1 ss. 112-119, Wrocław 2006.

[3] Dudziak, J., *Teoria okrętu*, Wydawnictwo Morskie, Gdańsk 1988.

[4] Ikeda, S., Ito, S., Someya, T., *An Experimental Marine Fluidised –Bed Boiler Plant*, Marine Engineers Rev, 1983,10, pp 15-17.

[5] Zeńczak, W., *Investigation of Fluidised Bed of the Physical Model of the Marine Fluidised Bed Boiler*, Journal of POLISH CIMAC, Vol.3, No.1,pp 183-190, Gdańsk ,2008.

The study financed from the means for the education within 2009 – 2012 as own research project No N N509 404536