S. GIL, J. OCHMAN, W. BIALIK

ISSN 0543-5846
METABK 55(4) 825-828 (2016)
UDC – UDK 621.771.777:621-462:621.41:621.791.052:66.04=111

A THERMAL STUDY OF PIPES WITH OUTER TRANSVERSE FINS

Received – Primljeno: 2015-11-26
Accepted – Prihvaćeno: 2016-04-20
Preliminary Note – Prethodno priopćenje

This paper provides results of thermal investigations on pipes with outer transverse fins produced by placing a strip, being a form of helical spring which functions as a radiator, on the basis pipe. The investigations were carried out at the facility that enables measurements with respect to both natural and forced convection. Performance of the investigated pipes was assessed in relation to a non-finned pipe and a pipe welded with the use of Metal Active Gas (MAG) technology. The experiments have shown that the finned pipe welding technology does not markedly affect their thermal efficiency, which has been confirmed by performed model calculations, while the welding technology has a crucial impact on their operating performance.

Key words: rolled pipe, strip, welded, thermal study

INTRODUCTION

This paper provides results of thermal investigations on heat pipes with outer transverse fins produced by placing a strip, being a form of helical spring which functions as a radiator, and its welding on the basis pipe using the laser and MAG technologies. This type of connection prevents the helical radiator from moving along the pipe and limits heat resistance at the place of contact of the basis pipe with the fin [1]. To produce this type of pipes, nearly all commercially available materials can be used and their operating temperature is up to 450 °C [2]. The experiments were carried out using a specially designed and constructed facility for thermal investigations on finned pipes in accordance with the methodology developed for earlier research studies [3-9].

The paper contains results of thermal investigations on six pipes with transverse, helically wound fins, for various welding technologies, one non-finned pipe and one pipe produced using the MAG technology.

The aim of the study was to determine and assess effects of the manufacturer-applied technology of fin winding and fusing with the basis pipe, i.e. the quality of fin-pipe connection, on its thermal efficiency as a function of temperature. A variety of solutions was represented by pipes provided for the investigations. Pipe lengths, fin sizes, their shape, graduation and material for all provided pipes were the same.

EXPERIMENTAL FACILITY

The measurements were performed at the facility that enables investigations with respect to both natural and forced convection. A biphase thermosiphon, where the condensate features counter flow towards the evaporator against vapour flowing to the condenser, was used as a heat exchanger. In order to make the experiments possibly closest to the real operating conditions for the investigated finned pipes, water was used as the working fluid to enable measurements within 100 - 220 °C and $1 \cdot 10^5$ - $2{,}5 \cdot 10^6$ Pa. Investigations at higher temperatures are also possible but they would require toluene as the working fluid for the temperature range of 220 - 260 °C or diphenyl mixture for 260 - 400 °C. The biphase thermosiphon as the heat exchanger at the designed experimental facility enables: transfer of large heat fluxes from small surfaces, heat transfer only within determined temperature ranges, reduction of heat load non-uniformity, operation without additional energy causing working fluid movement. Figure 1 presents a view of the facility intended for thermal investigations on finned pipes with the biphase thermosiphon as the heat exchanger is presented, and Figure 2 provides an

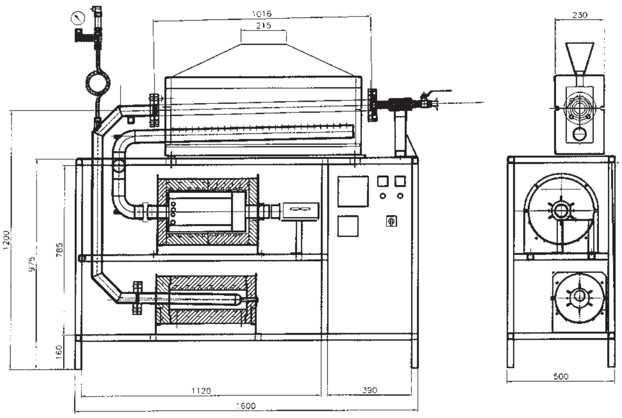

Figure 1 View of the facility intended for thermal investigations on finned pipes

S. Gil, J. Ochman, W. Bialik, Faculty of Materials Engineering and Metallurgy, Silesian University of Technology, Katowice, Poland

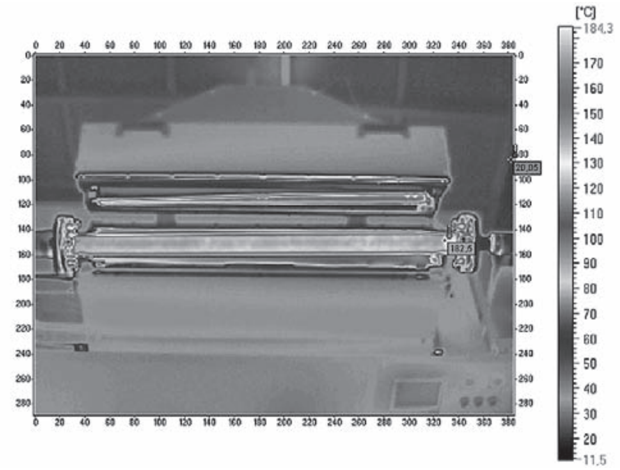

Figure 2 Thermal image of the pipe at the experimental facility

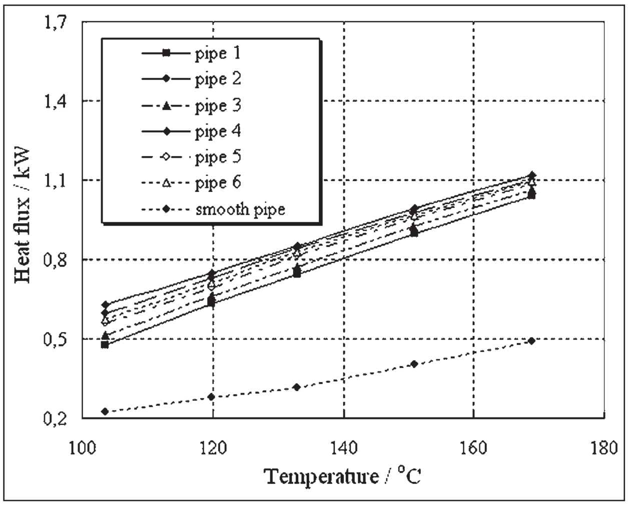

Figure 4 Heat flux transferred from the tinvestigated pipes to the agent "2"

image taken using a thermographic camera that confirms a very good temperature adjustment in the investigated pipe during the experiments.

RESULTS AND DISCUSSION

The thermal investigations were carried out for six sections of transversely finned pipes with helically wound fins (No. 1 - 6), produced using various welding technologies, as well as for one pipe produced by means of the MAG technology (No. 7) and one non-finned pipe (No. 8). In Figure 3, an image of finned rolled pipes is provided.

The investigations were carried out for the agent "1" temperature (water vapour and, following the phase transition, water) within 100 - 170 °C. The results obtained are provided in Figures 4 - 7.

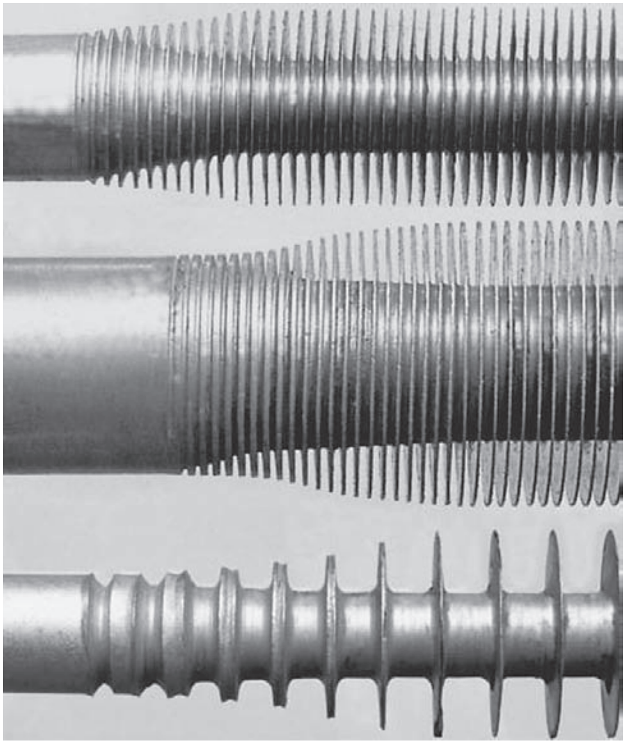

Figure 3 View and profiles of finned rolled pipes

In Figure 4, a measured value of heat flux transferred from the investigated pipe section to the agent "2" (air) under stabilized thermal conditions is presented. The pipe labels are consistent with the manufacturer's labels. Pipe 7 was produced using the MAG welding technology and the other pipes were produced by means of laser welding. Heat fluxes transferred from the investigated pipes (1 - 7) to the agent "2" differ at the utmost by approx. 0,16 kW at 105 °C and by approx. 0,1 kW at 170 °C.

A measured value of heat flux transferred from the investigated pipe section to the agent "2" under stabilized thermal conditions at the experimental facility, decreased by the heat flux transferred from a non-finned pipe under the same thermal conditions, is provided in Figure 5. Among the investigated pipes, pipe 7, produced using the MAG welding technology, demonstrated mean values.

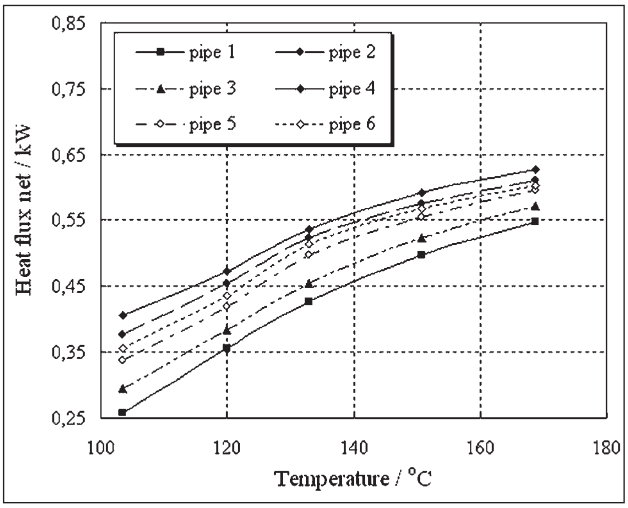

Figure 5 "Net" heat flux, i.e. heat flux transferred from the investigated pipe to the agent "2", decreased by heat flux transferred from the non-finned pipe

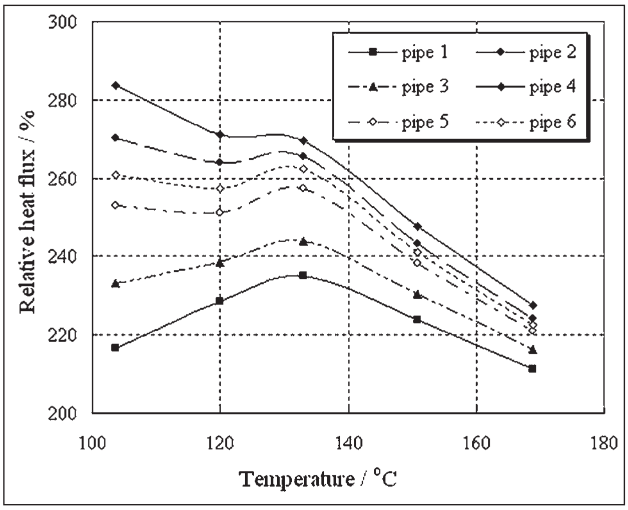

Figure 6 Heat flux transferred from the investigated pipes to the agent "2" in relation to the non-finned pipe

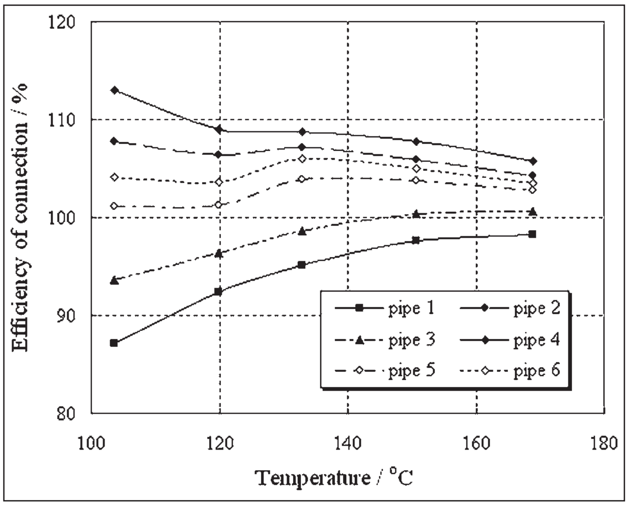

Figure 7 Ratio of heat flux transferred from the investigated pipe to the agent "2" to heat flux transferred from pipe 7 produced using the MAG technology

A value of heat flux transferred from the investigated pipe section to the agent "2" under stabilized thermal conditions at the experimental facility, in relation to the heat flux transferred to a non-finned pipe under the same thermal conditions, is provided in Figure 6. The greatest differences between the investigated pipes are observed at the lowest temperatures, i.e. under conditions where the transferred heat flux is mostly affected by convection. In this case, pipe 7, produced using the MAG welding technology, also demonstrated mean values among the investigated pipes.

The value of heat flux transferred from the investigated pipe section to the agent "2" under stabilized thermal conditions at the experimental facility, in relation to the heat flux transferred to pipe 7 (produced using the MAG welding technology) under the same thermal conditions, is provided in Figure 7. In this case, the greatest differences between the investigated pipes are also observed at the lowest temperatures.

In Figure 8, a schematic diagram of a defective connection between the fin and the basis pipe is presented.

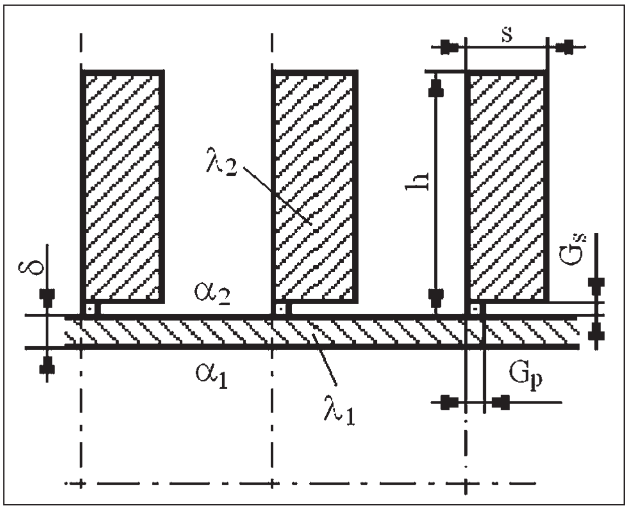

Figure 8 Schematic diagram of a defective connection between the fin and the basis pipe

Together with the equations provided above in the section "Problems of heat flow", it was used for model calculations.

In model calculations, the values of slot thickness G_s and the weld transverse diameter G_p were changed. The following parameters were used for calculations: thermal conductivity of the fin, λ_1 = 52 W/mK, thermal conductivity of the agent "2", λ_2 = 0,025 W/mK, fin thickness, s = 1,5 mm, fin height, h = 19 mm, and wall thickness of the pipe δ = 3 mm. The heat transfer coefficients α_1 and α_2 were calculated individually for all experiments.

Calculation results were considered in terms of: heat flux through the fin defectively connected to the basis pipe in relation to heat flux through the fin properly connected to the basis pipe, i.e. for G_p / s = 100 %. Results of model calculations are provided in Figure 9. They show that even a weld with a minimum profile provides good heat transfer conditions at its limited height but a defective weld, due to its rapid erosion, results in formation of a slot and, thus, markedly reduced fin performance.

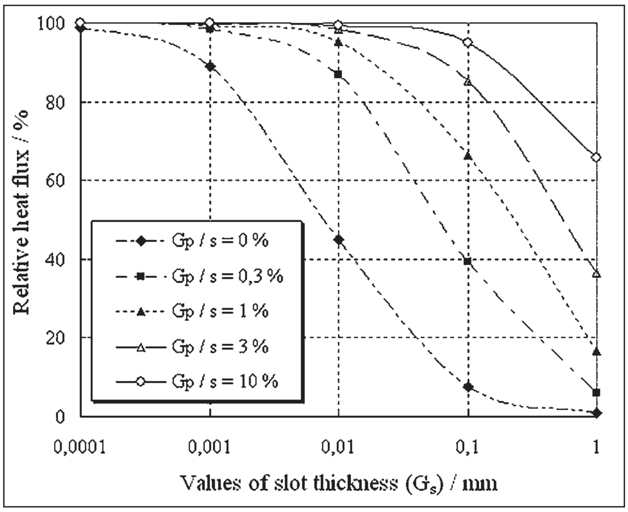

Figure 9 Relative heat flux through a fin defectively connected to the basis pipe

CONCLUSIONS

- The investigations on effects of the finned pipe welding technology on their thermal efficiency were carried out at the experimental facility intended for investigations on heat exchange of finned pipes with the biphase thermosiphon as the heat exchanger.
- The investigations were carried out on a smooth pipe, welded pipe produced using the MAG technology and 6 pipes welded by means of laser welding with various parameters.
- Performance of the investigated pipes was assessed in relation to a non-finned pipe and a pipe welded using the MAG technology.
- The investigations were carried out for the agent "1" temperature of 100 - 170 ^{o}C.
- The investigations have shown that the finned pipe welding technology does not markedly affect their thermal efficiency, which has been confirmed by the model calculations.
- The finned pipe welding technology has a crucial impact on their operating performance. This is demonstrated by the calculation model results provided in Figure 9. Even a weld with a minimum profile provides relatively good heat transfer conditions but a defective weld, due to its rapid erosion, may lead to markedly reduced fin performance resulting from formation of a slot at the defective weld location.

REFERENCES

[1] W. Pudlik: Wymiana i wymienniki ciepła. Wydawnictwo Politechniki Gdańskiej, Gdańsk 2012.

[2] J. Mitrovic: Handbook Heat Exchanger and Condenser Tubes, Tube Types – Material–Attributes – Machining. Publico Publications, Essen 2004.

[3] T. Hobler: Ruch ciepła i wymienniki. Wydawnictwo Naukowo - Techniczne, Warszawa 1986.

[4] K. Stephan: Wärmeleistung von Rippenrohren bei unvollkommener Befestigung der Rippen. Kältetechnik - Klimatisierung 18 (1966) 2, 41-48, Mannesmann-Forschungsbericht 338 (1966).

[5] B. Staniszewski: Wymiana ciepła podstawy teoretyczne. PWN, Warszawa 1979.

[6] E. Kostowski: Przepływ ciepła. Wydawnictwo Politechniki Śląskiej, Gliwice 2006.

[7] H. Walter, R. Hofmann: How can the heat transfer correlations for finned-tubes influence the numerical simulation of the dynamic behavior of a heat recovery steam generator? Applied Thermal Engineering 31 (2011) 405-417.

[8] B. Niezgoda-Żelasko, J. Żelasko: Free and forced convection on the outer surface of vertical longitudinally finned tubes. Experimental Thermal and Fluid Science 57 (2014) 145-156.

[9] Z. Iqbal, K.S. Syed, M. Ishaq: Optimal fin shape in finned double pipe with fully developed laminar flow. Applied Thermal Engineering 51 (2013) 1202-1223.

Note: The person responsible for the translation of the paper into the English language is Marzena Małgorzata Ochman, Certified Translator, Katowice, Poland