EXPERIMENTAL STUDY OF HEAT TRANSFER DURING ACETONE AND ETHANOL BOILING ON HORIZONTAL FINNED PIPES

A.V.Ovsiannik, M.N.Novikov, D.A.Drobyshevski, N.A.Valchenko
P.O.Sukhoi State Technical University of Gomel, pr. Octiabria No 48 ,
246746, Gomel, Republic of Belarus, tel. (0232) 48 35 79

Abstract

Experimental study of heat transfer intensity during acetone and ethanol boiling on finned surface at the atmospheric pressure in free movement in the range of heat fluxes of 8-63 kW/m^2 has been conducted. The results of boiling of these liquids on cross and longitudinal type finning with various fin geometry have been obtained. The dependencies of temperature head and heat transfer coefficient on a input heat flux have been obtained. Comparative analysis of the effect of the type and the geometry of finned surface has been conducted.

INTRODUCTION

Present day methods of heat exchange intensification during boiling on heat releasing surface can be divided into several groups: structurized surfaces, fins and porous coating. It should be noted that when choosing for practical use this or that method of heat exchange intensification it is necessary to take into account not only the efficiency of the surface itself, but its versatility for various heat transfer agents, adaptability to efficient manufacturing, technical effectiveness of heat exchange device assembly, durability requirements, surface dirt retention and operation features [1,2 et al]. According to the combination of the features required finned surfaces of various types became most widely used in modern commercial heat exchange devices. The advantages of these surfaces include technological effectiveness and manufacturing low cost, assembly technological effectiveness, wide range of heat fluxes, operation with contaminated heat transfer agents.

1. Experimental Equipment

To investigate heat exchange during liquid boiling an experimental stand has been developed at the GNU ITMO NANB the design of which and methods of experiments are presented in detail in [3]. Duralumin horizontal finned pipes manufactured by milling were used as experimental samples. To measure temperature head on the surface of the experimental samples at the fin bottom (base), mid-section and vertex chrome-aluminum alloy - copel differential thermocouples with the conductor diameter of 0.5 mm were caulked in. Experimental data were recorded and processed with the automated measuring system, made based on the analogue-digital converter of ADC32-1533 model of Analog Devices Company, data processing program ACD32GD 1.0. Heat transfer coefficient error was within 15%. Experimental sample characteristics are presented in the table.

Table

Experimental Sample Characteristics

№	Fin Type	d_v/d_o, mm	h, mm	s, mm	δ_v / δ_o	L_{fnd}, mm	L_o, mm	n, pcs
Longitudinal Finning								
1	triangular	47/25	11	4.33	0/4	280	310	10
2	trapezoid	47.5/25	11.25		2/4			
3	rectangular				4/4			
Cross Finning								
4	triangular	50/25	12.5	4	0/4	284	310	36
5	trapezoid				2/4			
6	parabolic				2/4			
7	rectangular				2/2	278		47

2. Results

Experimental study of heat transfer intensity during acetone and ethanol boiling on finned surface at the atmospheric pressure in free movement was conducted in the range of heat fluxes of 8-63 kW/m^2. Temperature head value between heat releasing surface and liquid is a determining parameter (other conditions being equal), characterizing heat exchange intensity between the given surface and the environment. So the study of the effect of the delivered (input) heat flux on temperature gradient in different points of the finned surface allowed to reveal qualitative and quantitative effect of this parameter on heat exchange during boiling. The heat flux delivered by an electric heater was divided into a heat flux, transferred by inter-fin surface and a heat flux through the bottom of the fins.

$$Q = Q_{i\text{-}f} + Q_f , \tag{1}$$

where

$$Q_f = Q \cdot \frac{F_o - F_{i\text{-}f}}{F_o} \text{ и } Q_{i\text{-}f} = Q \cdot \frac{F_{i\text{-}f}}{F_o}, \tag{2}$$

F_o - area of the basic (supporting) surface.

Heat flux densities on fins and inter-fin surface respectively are:

$$q_f = \frac{Q_f}{F_f} \text{ и } q_{i\text{-}f} = \frac{Q_{i\text{-}f}}{F_{i\text{-}f}} . \tag{3}$$

In Fig. 1, 2 the dependencies of temperature head at all elements of finned surface on input heat power during acetone boiling are shown.

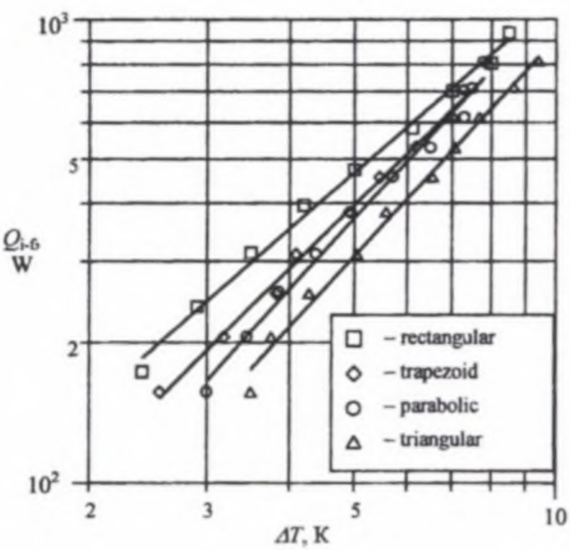


Fig.1. Experimental dependencies of average temperature head of basic surface on the heat flux, abstracted by the inter-fin surface for cross finning during acetone boiling

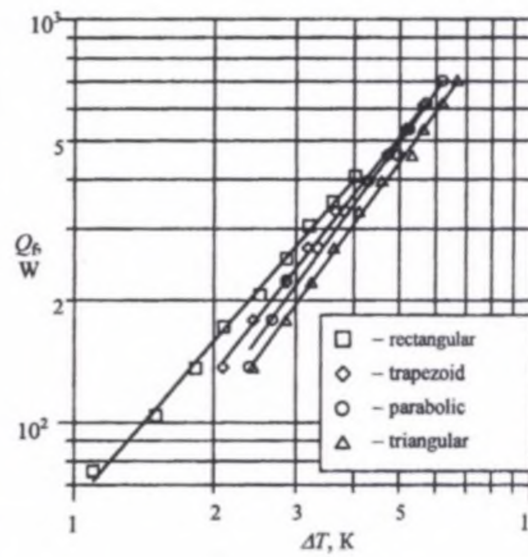


Fig.2. Experimental dependencies of average temperature head on the fin on the heat flux , abstracted by the fin for cross finning during acetone boiling

During boiling on finned surface with a rectangular fin profile lower temperature gradients have been obtained both for longitudinal and for cross type finning. This does not conflict with the known tendency towards temperature head decrease with heat exchange surface area increase.

Using the values of ΔT obtained heat transfer coefficients were determined dependent on a heat flux densities at all elements of finned surface. Following the analysis of the dependencies obtained one can make a conclusion that average coefficients of heat transfer on the fin are slightly dependent on the fin profile during free vapor phase abstraction, and for longitudinal finning the difference is extremely small (Fig.3, 4).

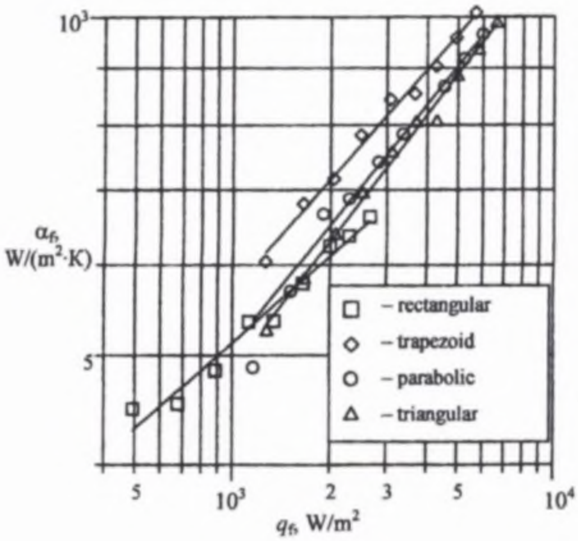


Fig.3. Dependencies of average heat transfer coefficient on the fin on the density of heat flux abstracted by fins for cross finning at acetone boiling

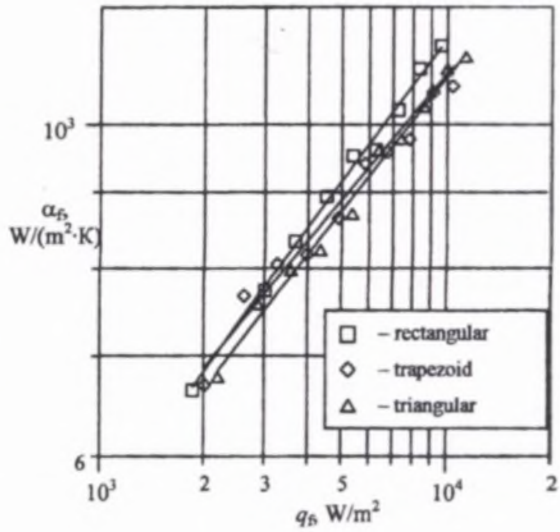
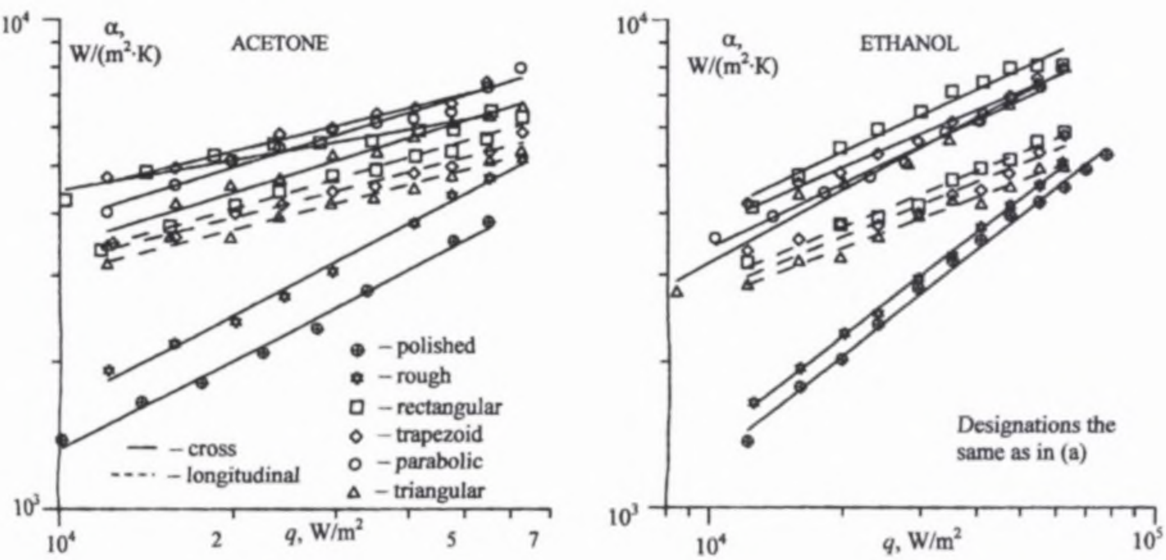


Fig.4. Dependencies of average heat transfer coefficient on the fin on the density of heat flux on the fin for longitudinal finning during ethanol boiling



a) b)

Fig.5. Dependencies of heat transfer coefficients on heat flux density on the sample basic surface for acetone (a) and ethanol (b)

CONCLUSIONS

Qualitative and quantitative dependencies *of temperature head on input power* and heat flux density were obtained during acetone and ethyl spirit boiling at the atmospheric pressure on finned surface.

The largest heat transfer coefficients, three times greater than such values for rough and 3-4 tim greater for polished surface , were obtained for the sample with cross rectangular finning.
It has been determined experimentally that at horizontal pipe positioning cross finning is 1.5 - 2 tim more efficient than longitudinal for the same fin type because of greater heat exchange surfa development and better vapor phase abstraction conditions.

The intensity of heat transfer on the fin is practically independent on the fin profile at sufficient inte fin distance, equal fin bottom thickness and fin height, and is determined by only thermophysic properties of boiling water.

Symbol Definition

GNU ITMO NANB - abbreviated name for the State Scientific Institution Heat and Mass Transfe Institute named after A.V. Lykov of the National Academy of Sciences of the Republic of Belarus.

α — heat transfer coefficient, $W/(m^2 \cdot K)$;
d — diameter, mm;
F — surface area, m^2;
h — fin height, mm;
L — length, mm;
p — pressure, N/m^2;
s — fin pitch, mm;
T — temperature, deg;
q — heat flux density, W/m^2.

Indexes:
v — fin vertex;
i-f — inter-fin surface;
s — conditions of saturation;
o — basic surface;
fnd — finned surface;
f — fin.

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