HEAT RESISTENT UNDERSPINNERET COOLER FOR FIBERGLASS MANUFACTURE

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Abstract

This paper is devoted to improve of an equipment used in fiberglass manufacture. The purpose of the present research was development of a heat resistant underspinneret cooler for cooling glass fibers going out from the spinnerets of container with the liquid glass mass. The heat resistance of underspinneret cooler has been achieved at the expense of using in a device design a principle of heat pipe. A new design of underspinneret cooler allows to decrease considerably the temperature on the underspinneret cooler parts surfaces and to make longer its service life.

KEYWORDS

miniature heat pipe, heat transfer limit, powder capillary structure, underspinneret cooler.

INTRODUCTION

Underspinneret coolers (USCs) are used in production process of fiberglass factories for cooling glass fibers going out from spinnerets. USC consists of a copper case (tube with diameter of about 20 mm) with unions for cooling water flow and a set of soldered to the case parallel located heat removal lamellae with the sizes of about 60x13x1.5 mm. Temperature of the bottom surface of a platinum container with the liquid glass mass makes about 1200^{o}C, and the distance between this hot surface and the lamellae doesn't surpass 8 mm. The influence of high temperature causes heating the lamellae up to temperature of about 700^{o}C. This factor in combination with influence of an aggressive atmosphere of acids vapor causes intensive corrosion of the lamellae. A result is complete failure of USC within a month and its replacement. Nickel-plating USC surfaces doesn't result essential increase of its service life because of quick destruction of nickel covering. Thus, it is required to replace at a factory about 1000 USC monthly. On purpose to this a factory needs a shop of the USC soldering with harmful working conditions of the working personnel. The replacement of USC requires a stop and new start of manufacture, what reduces the productivity and has a negative effect on quality of production.

In the present paper the design is described and some results of tests of heat resistant USC operating with use an evaporation-condensation cycle by a principle of a heat pipe are submitted.

DESIGN OF UNDERSPINNERET COOLER

An estimate calculation has showed, that during operate of USC in natural conditions of fiberglass manufacture the common radiation energy flow received with the whole lamella surface and transferred by heat conductance to cooling liquid makes about 60 Вт. Such heat transfer capability may be achieved at considerably less temperature difference by using latent heat of evaporation organized inside a hollow lamella.

A design of the USC is presented in Fig. 1. The outside case 1 (a copper tube with the closed end faces) has unions 2 for cooling water 3 flow. The copper tube 4 with the closed end faces is located inside case 1. Copper lamellae 5 having the sizes 65×13×1.5 mm pass through case 1 and they are soldered in the inside tube. The lamellae are hollow (wall thickness makes 0.5 mm), closed at outside end face and open inside the tube 4. On the inside surface of lamellae walls there is a porous layer with thickness of about 0.1 mm consisting of sintered copper powder. The internal spaces both of lamellae and tube 4 connected between themselves are isolated hermetically from environment and filled with

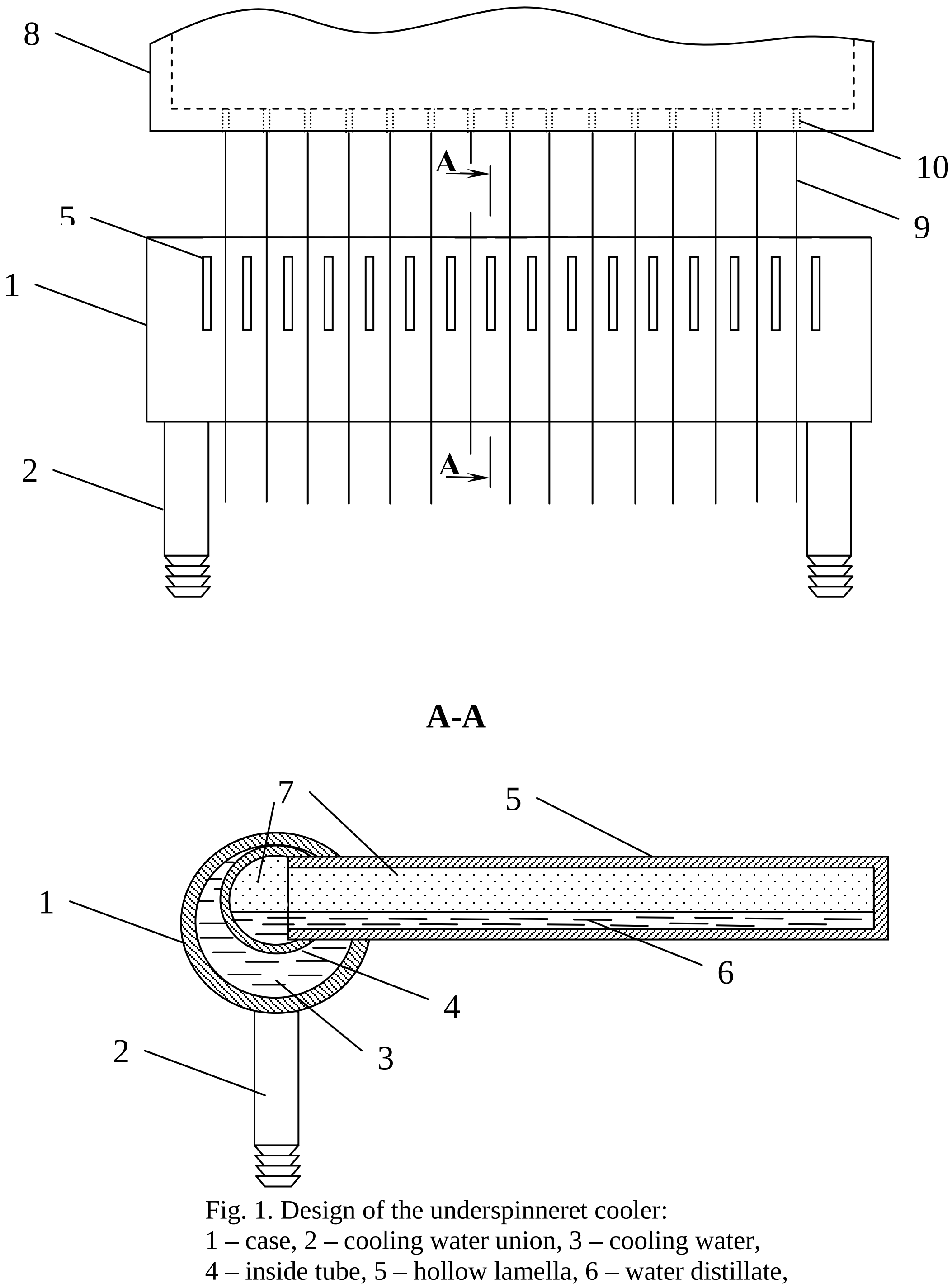

Fig. 1. Design of the underspinneret cooler:
1 – case, 2 – cooling water union, 3 – cooling water,
4 – inside tube, 5 – hollow lamella, 6 – water distillate,
7 – vapor, 8 - container with the liquid glass mass,
9 – glass fiber, 10 - spinneret

water distillate 6 and its vapor 7. Thus, in the USC design is used no other than a principle of heat pipe with hollow lamellae as an evaporator and inside tube 4 as a condenser.

The drawing of hollow lamella cross-section is presented in fig 2. The case of the lamella (thickness 1,5 mm) is formed with flat copper tubes having the wall thickness of 0,5 mm. On the inside surface of the case there is a porous layer of a capillary structure. The photograph of cross-section of the lamella wall with the capillary structure is presented in Fig. 3. For obtaining of the capillary structure a special technology have been developed. The capillary structure was molded and sintered

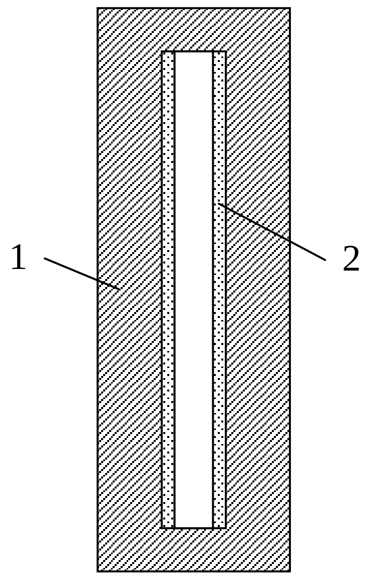

Fig. 2. The drawing of lamella cross-section:
1 – case, 2 – capillary structure

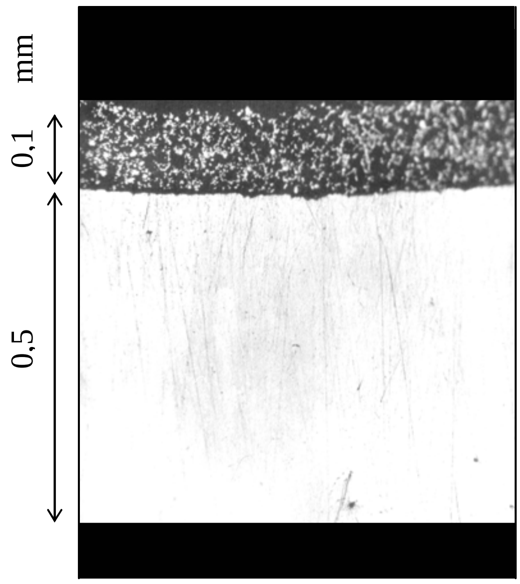

Fig. 3. The photograph of cross-section of lamella wall with the capillary structure

from copper powder with particle size of about 10 µm. The thickness of the capillary structure makes about 0,1 mm, its porosity – about 70 %, the average pore size – about 5 µm.

EXPERIMENTS

In order to check the serviceability of described USC design evaporation capability of separate lamella was tested. An experimental set-up was similar to one used for investigation of the simplest design of an open oscillatory heat pipe [1]. Experimental set-up is shown schematically in Fig. 4. Lamella open end face was dipped into water distillate whose level was regulated. Heating of lamella part situated outside the USC case was realized with electric heaters made of Ni-Cr thermic wires wound around the wall of the lamella over an electric insulation. Heat losses to the ambient were minimized by covering thermic wires with multiple folds of a thermal insulation material made of glass fiber. Temperature of closed outside end face measurements were performed by thermocouple. The heat was supplied by an electric source.

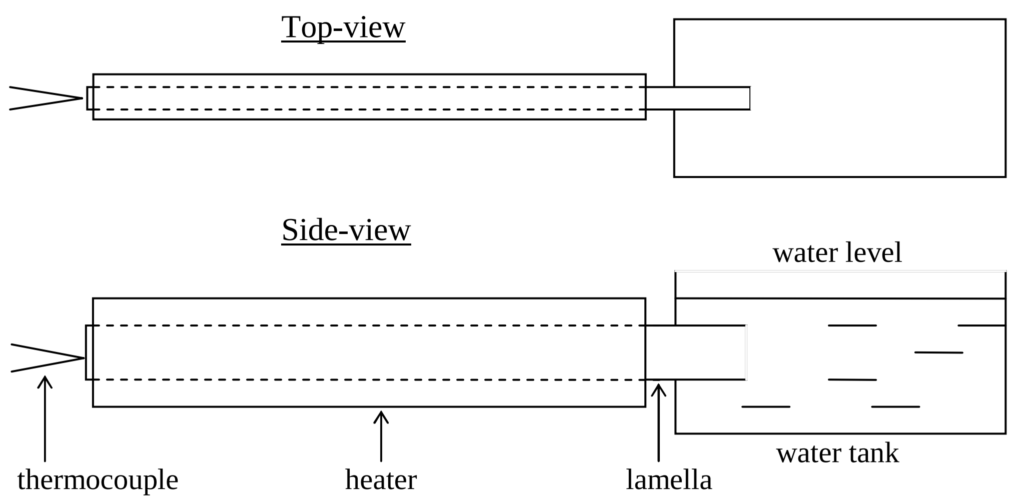

Fig. 4. Experimental set-up

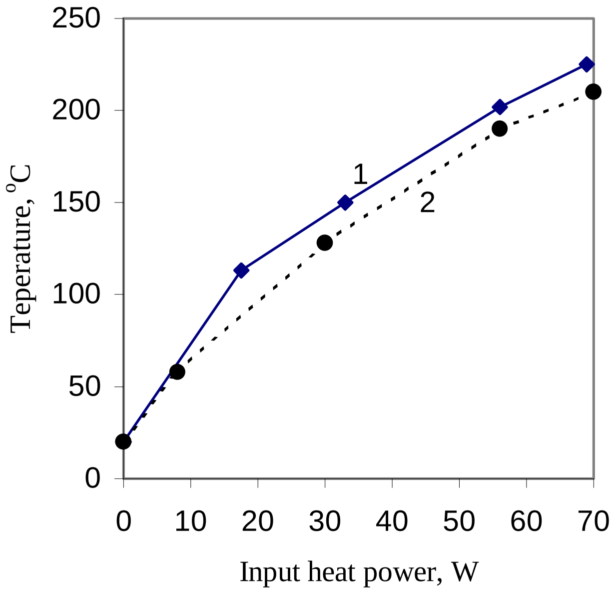

Fig. 5. Temperature of lamella closed end face as a function of input heat power:
1 – completely flooded,
2 – half flooded lamella end face

Results of experimental investigation of separate lamella evaporation capability are given in Fig. 5. The experimental data was obtained for different levels of water in feeding tank. Experimental points 1 correspond to case of full flooding the lamella open end face into water and experimental points 2 correspond to half flooding.

As it is seen in fig. 5, the open lamella evaporation capability of 60 W corresponds to temperature of closed end face of about 200 °C, what is considerably less in comparison to heat transfer capability of the lamella made of compact copper.

The water level has the visible influence upon temperature of lamella closed end face. This may be explained with peculiarity of vapor and liquid flows in this case. The vertical size of lamella inside channel is large enough. At this condition instead a liquid plugs and vapor bubbles type flow pattern occurs the liquid flowing in the bottom of the lamella and the vapor flowing in the lamella top [1].

Indeed, one can see from top-view point upon the water surface, that at the small quantities of input heat power (till 30 W) there is liquid flow only from lamella inside channel. This is the flow of warm water, which is being got warm at the expense of condensation of vapor that is being generated in the capillary structure. Could water moves in the opposite direction at bottom part of lamella and isn't visible from top-view point. At quantities of input heat power more 30 W the whole vapor quantity generated in the capillary structure isn't in time for full condensation and one can see both liquid and vapor bubbles flows from the top part of lamella inside channel.

CONCLUSION

A heat resistant underspinneret cooler for fiberglass manufacture has been developed. The heat resistance of USC has been achieved at the expense of using in a device design a principle of heat pipe with hollow lamellae as an evaporator. A hollow lamella having sizes 60×13×1.5 mm was tested concerning the evaporation capability. At the same input heat power the temperature of open lamella closed end face is considerably less in comparison to the lamella made of compact copper. A new design of USC allows to decrease considerably the temperature on the USC parts surfaces and to make longer its service life. An experimental sample of USC is passing industrial tests at the Polotsk factory «Steklovolokno» from June 1, 2003.

References

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