New Design Heaters Using Tubes Finned by Deforming Cutting Method

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Abstract: The article describes the results of research aimed at selecting and assigning technological processing parameters for obtaining outer fins of heat-exchange tubes by the deformational cutting method, for use in a new design of industrial water-air heaters. The thermohydraulic results of comparative engineering tests of new and standard design air-heaters are presented.

1. Introduction

Heat exchangers (HE) for heat discharge into the atmosphere from the cooled devices or for buildings and premises’ air heating are widespread in practically all branches of Russia’s economic complex. HE, using hot water as heat carrier, are one of the most efficient and economical heat exchangers for heating large premises. The design of HE (water heaters) should provide maximum efficiency in heat transfer of heat from hot water to heated air with minimum dimensions, metal consumption and price. The heat transfer conditions at the interface "hot surface - heated air" are limiting for the above factors due to the low heat transfer coefficient and the air low heat flux.

Therefore, the main focus is concentrated on the heat transfer coefficient increasing at the solid body - air interface. The low coefficient of heat transfer from the outer surface of the heat exchange elements to air conditions a large mass, size and cost of the HE, which can be reduced by the air contacting surface development. To increase the efficiency of heat transfer, innovative technical solutions are also used to change the organization of the heat carrier flow within a single module HE, changing its hydrodynamic parameters [1, 2], an example of such a HE is a new design heater (NDH) [3] (fig. 1).

For the development of an air contacting surface, pipe-plate and pipe HEs were most widely used. Pipe-type HE have advantages in terms of their manufacturability, which has a significant impact on the price of heat exchangers. Plain-pipe HE have a restricted use. At present in pipe-type HE systems for heating, cooling and air conditioning they use pipes with packed-on plate, spiral-wound, rolled-on, wire and other types of fins, as well as pipes with hole intensifiers [4]. Prefabricated structures of finned tubes with packed-on, wound and wire fins have a high thermal contact resistance and are not manufacturable. Rolled-on finning on monometallic pipes has low surface area increase factor after treatment. Bimetallic pipes with rolled finning are of high cost and low compactness due to the impossibility of obtaining small finning pitch.
Studies of convective heat transfer on surfaces with applied hole intensifiers have shown an increase in heat transfer by 35-40% with lagging behind in growth and even a decrease in aerodynamic resistance [5]. This method of heat transfer intensification is very promising, but the problems of technological order restrain its use.

Fig. 1. NDH Heater module

An alternative option that minimizes the shortcomings of existing technologies for the development of the outer surface of heat-exchanging pipes is the technology of deforming cutting (DC), based on the pipe billet surface layers undercutting and deforming them with the formation of spiral fins without forming chips (Fig.2).

Fig. 2. Finning by DC
The finning done by the DC have such advantages as: absence of thermal contact resistance, large compactness of HE due to the possibility of obtaining small fining pitches, high manufacturability and productivity of the pipe finning process.

2. Development and methodology

At the Federal Research Center for Coal and Coal Chemistry of the Russian Academy of Sciences Siberian Branch, a bench installation for comparative hydrodynamic and thermal engineering studies of air-water air heaters (water heaters) of various types was developed and manufactured. In order to study the hydrodynamic and thermotechnical parameters, a methodology was developed and comparative tests were carried out on this stand of the NDH module and the factory module of the water air heater (WAH). The heater modules had identical overall dimensions, the number and type of heat exchange pipes, and the heat transfer surface. The difference consisted in the hydraulic piping (connection of heat-exchange pipes) and, accordingly, the organization of the heat carrier flow inside the single module of the NDH.

Ventilation air supply was provided by two independent axial fans with the same parameters. The parameters monitoring during stand operation: flow rate, temperature, pressure were provided by measuring instrumentation systems, including heat meter “Vzlet” TSRV-020 with data recording on a computer.

The thermo-technical characteristics obtained as a result of comparative tests showed that the NDH module more efficiently transfers heat to the air environment in comparison with the WAH module, as seen from the lower temperature of the return water and the higher air temperature at the exit of the bench installation. This trend also persists with the flow rate change of the heat carrier and is graphically presented in Figure 3.

![Fig. 3. Comparative thermohydraulic characteristics of the NDH and WAH modules](image)

According to the authors' estimates, the application of the DC method for the NDH heating pipes’ surface development [3] in conjunction with the technical solutions for performing the connection of heat-exchange finned pipes in a row and rows among themselves in a module, one by one in a single
branch and branches between each other by interpipe transitions in the form of steeply bent branches or tangential-slit transitions will additionally allow:
- to reduce the metal consumption of HE (air heater) by an average of 10-12% compared to domestic and imported air heaters;
- to increase the heat carrier velocity by 30%;
- to reduce the heat carrier and energy consumption for its pumping;
- to achieve the HE heat transfer efficiency increase by 30-40% [7].

Using DC method and lathes, finning can be obtained with pitches of 0.2 to 2.5 mm, with a width of inter-fin clearance in the range 0.05-0.65 (usually 0.5) of the fin pitch [8].

The maximum fin height when processing copper for large finning pitches is 4 mm. In addition to the fin pitch, the fin height also depends on the thickness of the initial workpiece wall and can not be more than twice of its value. When processing titanium, copper-nickel alloys, low-carbon and corrosion-resistant steels, the maximum fin height is 3-5 pitches of finning, but not more than 3 mm. Due to the spread in the pipe workpiece wall thickness, which is 10% of the normal accuracy pipe nominal value [9], the residual thickness of the pipe wall after treatment with DC is not recommended to be less than 0.5 mm. Fine-pitch finning with a narrow inter-fin gap is effective for heat exchange processes based on phase transitions [10]. For air heat exchangers in conditions of convective heat exchange of air blown at low velocities (up to 0.5 m/s), it is necessary to provide a width of inter-fin gap of at least 0.3 mm with the maximum increase of the pipe area after the finning operation [11].

The DC method allows processing both annealed and non-annealed workpieces. The more plastic the pipe workpiece is, the wider are the method possibilities, however, work on a conventional lathe with long annealed (soft) workpieces is inconvenient, since long pipe workpieces (especially copper ones) are easily bent and additional measures are required to eliminate pipe bending. For this reason, non-annealed (solid or semi-solid) copper and aluminum pipe workpieces are recommended. When finning steel, titanium or copper-nickel pipes, it is advisable to use annealed workpieces, which in their properties have an increased plasticity with sufficient technological rigidity.

Pipe workpieces intended for processing by DC method must not have nicks, upset forgings and dents. The deflection of the pipe workpiece should not exceed the deflection, regulated by GOST 617-2006 (for diameters up to 60 mm this tolerance is 2...3 mm per running meter of the pipe, depending on the class of its accuracy). To implement the DC process, lathes can be used with both manual and programmed control. When an automatic chuck is available, computer controlled machines provide the ability to rearrange a long pipe in an automatic cycle.

3. Results and discussion
As the initial workpiece, a copper pipe of grade M2 with 20 mm outer diameter and 2 mm wall thickness DKRNK was used, according to GOST 617-2006 (cold-deformed, round, normal precision, semi-solid). The total length of the samples was 320 mm, the finned section length was 300 mm, the smooth endings length was 10 mm each.

As a tool for making samples, high-speed steel P6M5 was used as tool material. The DC tool was manufactured by way of sharpening of the high-speed workpiece 120 mm long and 30x20 mm cross section in three planes. The pipes’ finning was done by DC method using a 1E61MT screw-cutting lathe. The tool for DC 2 was fixed in the tool holding device 1 of the machine (Figure 4). The machine was equipped with a moving lunette 4, mounted on the support of the machine. To reduce the friction between the rotating pipe and the movable work rest 4, a rolling bearing 5 was used, into which a bushing 6 having an inner diameter of 20 mm was pressed. The pipe workpiece was clamped in a three-jaw chuck of the machine through a split bushing (the pipe fixing in the chuck in Fig. 2 is not shown).
The feed was carried out from the running roller and was 1.5 mm/rev, cutting depth \( t = 1.2 \text{ mm} \). The fins were produced at the spindle speed \( n = 800 \text{ rpm} \). The fins’ cutting time at 300 mm section was 15 seconds. The photo of the obtained samples is shown in Fig. 5a. Based on the measuring results of the finned pipes sections (Figure 5b) on an instrumental microscope UIM23, the following geometric parameters of the finned structure were obtained, which are presented in Table 1.

![Diagram of pipe finning setup](image)

**Fig. 4.** - Adjustment for pipe finning by DC method:
1 - cutting tool, 2 - DC cutter, 3 - pipe workpiece, 4 - moving work rest, 5 - rolling bearing, 6 - bushing, pressed into the rolling bearing, 7 – the obtained finning

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![Image of finned pipes](image)

**Fig. 5 – Pipes finned by DC:**
a – photo of finished pipe samples for NDH module, b – section of the finning obtained
Table 1. Geometric parameters of samples’ finning

| Parameter                                      | Value                  |
|------------------------------------------------|------------------------|
| Finning pitch S, mm                            | 1.5                    |
| Fin gap width, b, mm                           | 0.95                   |
| Fin thickness, a, mm                           | 0.55                   |
| Fin height, h, mm                              | 3.3…3.4*              |
| Residual pipe wall thickness , mm              | 0.8…0.85*             |
| Diameter at the fin tops, Dp, mm               | 24.0                   |

* - Measurements for diametrically located sections

4. Conclusion

As a result of the performed works, it is shown that the deforming cutting method is promising for the NDH heaters pipes outer surface development, since it allows to obtain highly efficient small pitch finning, high-efficiency, waste-free, does not require the use of lubricating-cooling technological media, is realized with a relatively simple cutting-deforming tool, does not require any specialized equipment.

The generalizing thermotechnical characteristics of the NDH air-heater module and the factory-made WAH air-heater module obtained confirmed the NDH heating systems constructive solution in the form of series-connected heat exchange pipes of the same cross section in rows and next to each other advantages.

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