

[54] **METHOD OF FORMING HEAT TRANSMISSIVE WALL SURFACE**

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3,768,290 10/1973 Zatell 29/157.3 B

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[57] **ABSTRACT**

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113/118 A; 165/133

A plurality of extremely fine grooves are formed on one side of a heat transmissive wall, and there are also provided a plurality of fine second grooves which are substantially parallel and closely adjacent to each other and which cross the first-said grooves. Fine notched ribs are formed between said second grooves, with the end portions thereof being rubbed and stretched transversely and connected to the adjoining ribs.

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[58] Field of Search. 29/157.3 R, 157.3 A, 157.3 B,
29/DIG. 23, 470.3; 113/118 A, 118 R;
165/133, 181

[56] **References Cited**
UNITED STATES PATENTS

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11 Claims, 2 Drawing Figures

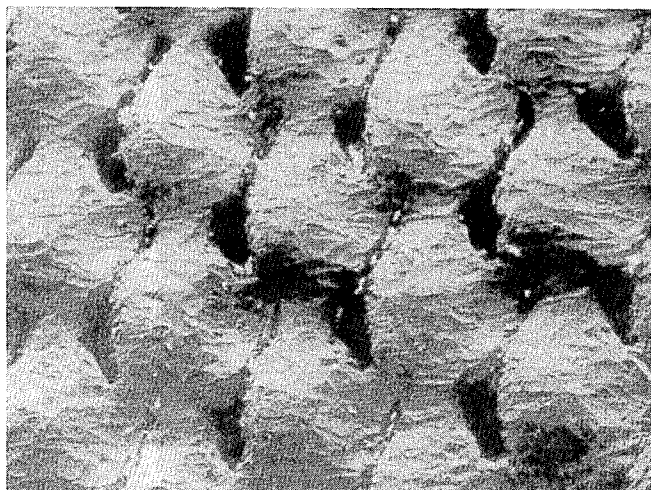


FIG. 1

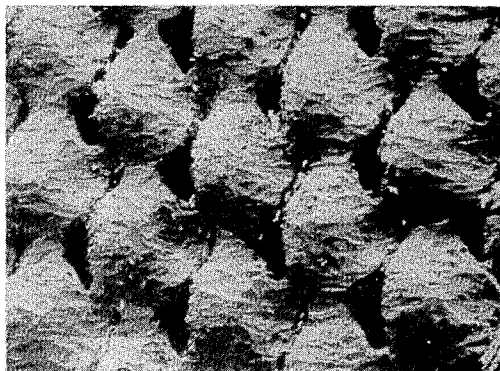
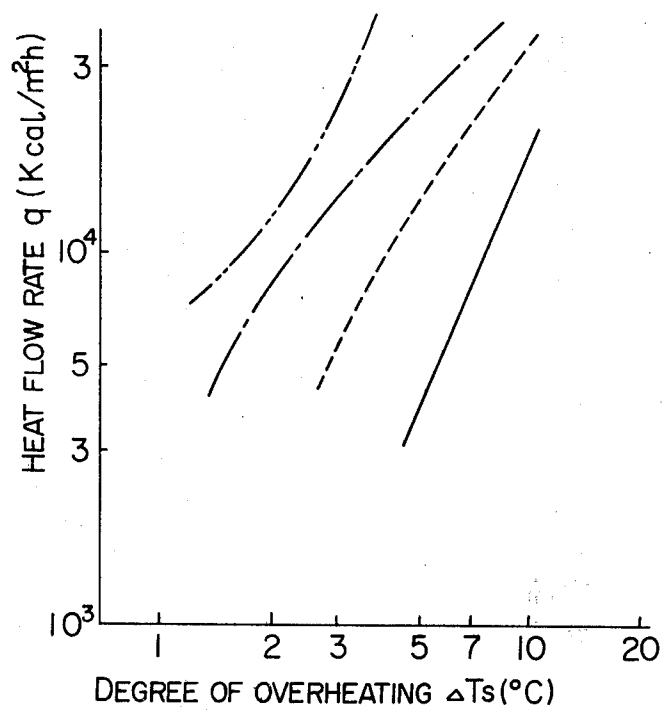


FIG. 2



METHOD OF FORMING HEAT TRANSMISSIVE WALL SURFACE

BACKGROUND OF THE INVENTION

In order to accomplish effective heat transmission from the surface of a plate, pipe or such into a liquid contacted therewith, such as for example liquid nitrogen, liquid oxygen, alcohol, water or the like, it has been proposed to roughen the surface of the plate, etc., by providing a porous layer of pulverized metal on said surface.

Such roughened wall surface produces a number of active boiling spots throughout the surface layer so that the heat transmitting or transferring efficiency is markedly improved as compared with the wall which is merely provided with fins or the like to enlarge the surface area. However, in such heat transmitting wall, the flow (convection) of the liquid that promotes heat transfer is limited to a certain locality and hence it is impossible to obtain an overall heat transmitting effect. Further, if some impurities, such as oil, are included in the liquid, the fine pores communicating with one another in the layer may be clogged, inviting reduction of the heat transmitting efficiency.

SUMMARY OF THE INVENTION

The present inventors have previously proposed a heat transmissive wall provided on one side thereof with a plurality of extremely fine voids arranged substantially parallel to each other and communicated with the outside through small pores. Such wall construction permits substantial rectification of the entire liquid by virtue of fine voids and ensures perfect retention of vapor, resulting in even more enhanced heat transmitting efficiency than obtainable with the wall provided with a porous layer on its surface.

The present invention proposes a method whereby such improved heat transmissive wall can be obtained.

According to the present invention, such improved heat transmissive wall can be obtained by providing extremely small ribs between the fine grooves formed on one side of the wall and connecting the ends of said ribs with the adjoining ribs.

More specifically, the method of the present invention features the following steps: firstly a multiplicity of fine first grooves and a multiplicity of similar fine second grooves crossing said first grooves and arranged substantially parallel and closely adjacent to each other are formed on one side of a heat transmissive wall, and then the ends of the small notched ribs formed between said second grooves are frictionally rubbed and stretched transversely and connected to the adjoining ribs.

The term "heat transmitting or transmissive wall" used here refers generically to the walls of the pipes, plates and the like which are made of copper, aluminum or other good heat conductive metals. Therefore, the small voids formed in such wall may be of any suitable configuration such as linear, helical or ring-shaped, and the grooves that provide such voids may be formed by any known method such as cutting or rolling. In case of employing cutting, it is preferred to use a "plow-up" type cutting method that causes deformation as in plowing up, rather than a method which causes cut-off. Such cutting work can be accomplished with ease by selecting a cutting edge of a suitable configuration and by adjusting the cutting speed.

Of the fine grooves formed in such way, the first grooves become the cutouts in the small ribs formed between the second grooves. They also serve as minute through-holes in the upper walls of the small voids which are formed by the succeeding frictional working. They will therefore become useless if they are eliminated or worked off during such frictional working, so that it is desirable that each of the first grooves is provided with a certain suitable width in its inlet opening. In certain applications of the heat transmissive wall, said minute through-holes formed in the grooves in the above-described way may be diminished in their serviceability. In such cases, the first grooves may be formed concentrically in certain localities.

The second grooves formed crossing the first grooves are the parts that become the small voids created by deformation of the small ribs formed between the adjoining second grooves. It is therefore desirable that these second grooves are somewhat deeper than the first grooves, but their width may be small in comparison with their depth.

The ends of the small ribs formed between the second grooves with formation of such grooves are frictionally worked and stretched in the transverse direction and connected to the adjoining ribs at a middle part. Such frictional working may be accomplished, for instance, by using a method employing a wire brush or roll rotated at high speed in pressed contact with said rib ends. The thus worked small rib ends are softened or fused and stretched laterally to adhere fast to a middle part of each adjoining rib, thus forming a wall well resistant to the boiling pressure in the formed small voids. The wall surface is also moderately roughened thereby to give rise to a number of boiling spots.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a photograph, magnified 50 times, of a part of the surface of a heat transmissive pipe obtained according to an embodiment of the method of the present invention; and

FIG. 2 is a graph showing the heat transmitting characteristics of said heat transmissive pipe.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, there is photographically shown on a 50-times magnified scale, a part of the surface of a heat transmissive pipe obtained by working the surface of a copper pipe according to the method of the present invention. The relatively large dark parts seen sporadically on the surface indicate the minute through-holes formed in the upper walls of the small voids. This surface has been obtained by performing knurling, cutting and wire brushing successively in that order.

The knurling was accomplished in the following way. A knurling unit provided with a fine knurling wheel or a roll formed with a plurality of helical closely adjacent knurling ridges is secured to a side of the tool rest of a lathe, then said roll is pressed against the surface of a copper pipe fixed at one end to the chuck of the lathe before practicing the cutting of the second grooves, and then said copper pipe is rotated while moving the tool rest along the lead screw.

This knurling work has produced on the surface of said copper pipe a plurality of fine grooves which are inclined at the angle of 45° relative to the axis of the

pipe and which are continuous helically and closely adjacent to each other. These fine grooves are the first grooves.

It is desirable that these first grooves have the depth within the range of about 0.05 to 0.3 mm and exist with density of less than 1 mm pitch.

In the surface shown in the photograph of FIG. 1, there were formed the V-shaped grooves with depth of 0.15 mm and density of 0.5 mm pitch.

The cutting was practiced after formation of said first grooves by pressedly attaching a grooving cutter mounted at the other side of the tool rest against the revolving copper pipe and moving the tool rest little by little along the lead screw. The cutting was of the type in which the copper pipe surface is not cut off but de-

formed. This cutting work has produced on the pipe surface a plurality of fine grooves which cross the above-said first grooves and which are continuous helically and closely adjacent to each other, as well as a plurality of fine ribs separated by said second grooves and each being formed with a small V-shaped notch along a part extending from the end to a middle point.

These second grooves preferably have a depth equal to or greater than that of the first grooves and exist at density of less than 1 mm pitch.

The ribs formed with formation of the second grooves are necessarily extremely small in size, but as they are formed by deformation of the pipe surface by the cutting work after the fashion of "plow-out", the ends thereof project out more from the pipe surface than before the cutting work. Therefore, the depth of the second grooves after the cutting work is greater than the depth of cut by the grooving cutter.

In forming the surface seen in FIG. 1, the cutting work has been performed with the depth of cut of 0.4 mm and at density of 0.4 mm pitch.

The thus formed second grooves crossed the first grooves at the angle of about 90° and presented a continuous helical configuration with depth of 0.76 mm, while the fine ribs formed simultaneously had thickness of about 0.2 mm and projected 0.58 mm from the surface of the copper pipe. The ends of these ribs were tapered.

The wire brushing that succeeded the above-said formation of grooves was practiced by removing the copper pipe from the lathe upon completion of the grooving work and passing said pipe through a brushing unit. The brushing unit comprises a plurality of wire brush wheels arranged radially along the passage of the copper pipe so that they will contact the entire periphery of the passing pipe and also adapted to be rotatable at high speed and movable back and forth relative the axis of said passage. Arrangement is also made such as to allow movement of the copper pipe at a constant speed. It is of course possible to make arrangement such that the copper pipe is fixed stationary while the wire brush wheels are movable.

Each wire brush wheel is adjusted such that its outer periphery will contact a circle slightly smaller than the outer diameter of the fine ribs formed on the copper pipe, and when said copper pipe is passed through its passage, the end portions of the ribs are frictionally rubbed successively by the high-speed rotating wire brushes and softened and deformed by the friction heat that develops resultantly, whereby said end portions of

the ribs are stretched thinly and laterally without cut off.

Consequently, the end of the thinly stretched copper film is pressed against and connected to a middle part of each of the adjoining ribs to close the second grooves, and small voids or cavities continues helically and communicating with the outside through small notched through-holes are formed below the thin copper film. The surface of the thin copper film constituting the upper walls of said voids and the surface of the heat transmissive pipe is roughened to present an intricate ruggedness as seen in FIG. 1. Although the small through-holes formed in accordance with the numerical figures of the first grooves are complicated and not constant as seen in FIG. 1, their size is within the range of 0.06 to 0.4 mm².

In FIG. 2, the curve shown by a double-dotted chain line expresses the heat transmitting characteristics of the heat transmissive pipe having a surface such as seen in FIG. 1. It is obvious that these characteristics are far superior to those of the flat surface shown by the solid line, those of the finned surface shown by the broken line and those of the porous layer covered surface shown by the single-dotted chain line in FIG. 2. Such excellent heat transmitting characteristics are ascribed to the presence of the above-said fine voids.

If a high-temperature object is placed in the heat transmissive pipe of the present invention and then immersed in a liquid, the small voids are filled with the liquid passed therein through the through-holes, and the liquid which entered said voids is immediately heated and boiled to produce bubbles. Since the small voids are arranged continuous circumferentially, a substantial portion of the bubbles rise up in the voids in the form as they are or while growing, and eject out in the form of microscopic vapor bubbles from the upper small through-holes into the liquid enveloping the heat transmissive pipe. As a result, the bubbles are reserved, though transiently, in the voids, whereby the bubbles are reduced to the thickness of the extremely thin liquid film present between the void walls through-out most of the heat transmitting distance, and also intrusion of the liquid into the voids from the lower through-holes is induced to cause a voluminous flow in the entire liquid, thus allowing accomplishment of very effective heat exchange.

The above-said results are obtained when the heat transmissive pipe is used by positioning it horizontally. In case the pipe is used in a vertical state, the described characteristics are somewhat deteriorated due to, for one thing, the tunnel effect of the voids. In such a case, it is desirable to form the fine voids parallel to the axis of the pipe or with a slight inclination thereto, and a heat transmissive pipe having such voids can be shaped in the same way as described above.

While the foregoing description concerns a heat transmissive pipe, the above-said change of characteristics also holds true with a heat transmissive plate. Shaping of a heat transmissive plate requires more time and labor than for the pipe, but such shaping will be greatly simplified and expedited by improving the groove forming tools and apparatus.

According to the present invention, as apparent from the foregoing explanation, a plurality of fine grooves are formed on one side of a heat transmissive wall to provide a number of boiling spots, and the ends of the small ribs formed between said grooves are frictionally

rubbed and connected to the adjoining ribs, so as to form the voids which permit reservation of bubbles effective for heat transmission and which are also useful for rectifying the liquid flow, whereby there can be obtained a splended heat transmissive wall which is far effective than a wall provided with a porous layer on its surface. Further, since the small through-holes communicating the interior of the voids with the outside are formed simultaneously with formation of the voids by utilizing the previously formed grooves, the working involved is simple and easy and no void deformation takes place, and thus there can be obtained a high-quality heat transmissive pipe at high efficiency.

What is claim is:

1. A method of forming a heat transmissive wall surface comprising the steps of forming a plurality of fine first grooves on one side of a heat transmissive wall, while forming a plurality of fine second grooves which cross said first grooves and which are substantially parallel and closely adjacent to each other, then frictionally heating by rubbing and stretching transversely the ends of the small notched ribs formed between said second grooves and fusingly connecting said ends to the adjoining ribs.

2. The method according to claim 1, in which the respective grooves are formed by rolling, and frictional rubbing of the rib ends is accomplished by wire brushing.

3. The method according to claim 1, in which said respective grooves are formed by cutting, and frictional rubbing of the rib ends is accomplished by wire brush-

ing.

4. The method according to claim 1, in which the first grooves are formed by rolling and the second grooves by cutting, and frictional rubbing of the rib ends is accomplished by wire brushing.

5. The method according to claim 2, in which the first grooves are formed by knurling.

6. The method according to claim 3, in which the second grooves are formed by a cutting method which does not cut off the wall surface but deforms it.

7. The method according to claim 4, in which the second grooves are formed by a cutting method which does not cut off the wall surface but deforms it.

8. The method according to claim 5, in which the second grooves are formed by a cutting method which does not cut off the wall surface but deforms it.

9. The method according to claim 1, in which continuously extending cavities are formed within the surface by said step of fusingly connecting said ends of the ribs between said second grooves, said cavities communicating with the exterior of the surface by through-holes formed by said first grooves.

10. The method according to claim 9, in which said second grooves have a depth equal to or greater than that of said first grooves.

11. The method according to claim 9, in which said cavities effect flow of a liquid therein from respective lower through-holes to respective upper through-holes, thereby enhancing heat exchange from the heat transmissive wall to said liquid.

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