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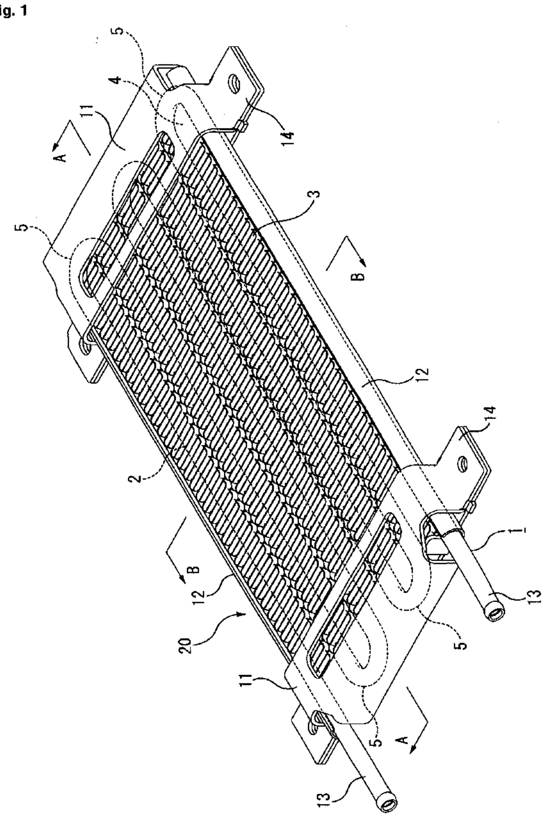
(54) **HEAT EXCHANGER**

(57) A heat exchanger wherein the pipe member is formed in a single stage to reduce the height of the heat exchanger in the thickness direction thereof to thereby enable the heat exchanger to be satisfactorily mounted below the floor of an automobile and wherein the pipe member is prevented from being broken by a stone flipped up by the automobile during running thereof. A heat exchanger comprises: fin members (3) formed as corrugated fins and having engagement recesses (8) formed in curved sections (6); and a pipe member (1) formed by connecting straight pipe sections (2) by U-shaped bend sections (5), the straight pipe sections (2) being arranged by means of the fin members (3). In a state in which the straight pipe sections (2) are engaged with the engagement recesses (8) of the fin members (3), the outer diameter of the pipe member (1) is in the range of 8 to 12 mm, and the facing distance (17) between the fin members (3) is in the range of 0.5 to 5.0 mm. Also, the height of the protrusion of the fin members (3) is set to a value which is less than or equal to 11 mm and which, when the facing distance (17) is within the range of 0.5 to 5. 0 mm, satisfies the formula of $y \geq 2.46\ x^{-0.29}$ (y: (the height of the protrusion of the fin members (3) from the surface of the pipe member (1))/(the facing distance (17) between curved top sections (15)), x: the facing distance (17) between the curved top sections (15)).

Fig. 1



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Description

Technical Field

[0001] The present invention relates to an air-cooled heat exchanger chiefly for installation in an automobile under a floor or in a lower part of an engine compartment thereof, particularly at the bottom of an engine front end or the like.

Technical Background

[0002] Conventionally, as a heat exchanger for automotive and other applications, a heat exchanger has been generally known, as shown in Patent document 1, that is composed of a fin member of corrugated shape arranged on a meanderingly formed pipe member. This heat exchanger, while being compact, by the meandering formation of the pipe member enables to make the flow path of the fluid circulating within the pipe member long, and by using the fin member of corrugated shape enables a large number of fins to be arranged, such that an improved heat exchange performance can be achieved.

Prior Art Documents

Patent Documents

[0003] Patent document 1: JP 2005 201622 A

Outline of the Invention

Problems to be solved by the Invention

[0004] However, whereas it is necessary to reduce the height in the thickness direction in particular if a heat exchanger is to be installed in a narrow space such as under the floor of an automobile or the lower engine compartment thereof, the height in the thickness direction of a heat exchanger of the kind shown in Patent document 1 is high, as is shown in Fig. 18 of Patent document 1, due to the pipe member being formed in two stages. Here, as a measure to reduce the height in the thickness direction over the invention disclosed by Patent document 1, it is conceivable to bring the two-stage pipe member into a single-stage form, at the same time shortening the formation width of the fin member in the thickness direction of the heat exchanger. However, if the formation width of the fin member is made too short, the surface of the pipe member to which the fin member is attached is exposed to the outside rather than the fin member. Therefore, a stone flipped up from the road surface during driving may easily hit the exposed surface of the pipe member, and in case the flying stone directly hits the pipe member, it is feared that a situation arises where the portion of the pipe member that was hit is damaged such that an indentation is formed, stress concentration due to external forces from vibration and the like occurs at the indentation, and the pipe member breaks.

[0005] The present invention attempts to solve the above-mentioned problem, by meanderingly forming the pipe member into a single stage to achieve a low height in the thickness direction of the heat exchanger such that the installability under the floor, in the lower engine compartment etc. of an automobile is rendered favourable, at the same time aiming to obtain a heat exchanger that enables to prevent a situation where a stone flipped up from the road surface during driving damages the pipe member by direct contact, stress concentration due to external forces from vibration and the like occurs at the indentation formed by the damage, and the pipe member breaks.

Means for Solving the Problem

[0006] The present invention, in order to solve the above-mentioned problem, comprises a plurality of fin members formed by repeatedly folding a plate material over itself into a corrugated shape to form corrugated fins, wherein curved sections that are formed due to the folding are press-deformed into a recessed shape to form engagement recesses, and a meanderingly shaped pipe member including a plurality of straight pipe sections arranged in parallels with the fin members in-between as well as U-shaped return bends for the straight pipe sections, wherein the straight pipe sections of the pipe member are engaged with the engagement recesses of the fin members. Because, in the invention as given above, fin members formed with corrugated fins are mounted to a pipe member of meandering shape that is formed integrally including multiple straight pipe sections, it is easy to arrange a plurality of fins on the pipe member, which enables to simplify manufacturing.

[0007] Because the fin members are formed by corrugated fins, the presence of curved sections formed between the individual fins of the corrugated fins furthermore enables the surface area of the fin members to be made large. Consequently, it becomes possible to efficiently dissipate heat from the pipe member, thus enabling to improve the heat exchange performance. Furthermore, by adopting the above structure a single-stage heat exchanger is formed, different from the two-stage heat exchanger disclosed in Patent document 1, which enables to render the product height in the thickness direction low, such that the installability under the floor of an automobile can be made favourable.

[0008] Also, the outer diameter of the pipe member is set to within 8 mm to 12 mm. If the outer diameter of the pipe member is less than 8 mm, especially when using oil, gasoline, petroleum distillate and the like as pipe fluid, situations will arise where the pressure loss of the fluid becomes large such that a required flow rate becomes difficult to secure, the flow rate diminishes such that a desired heat exchange duty becomes difficult to fulfil, or the pressure loss exceeds a threshold value such that use becomes impossible. If on the other hand it is greater than 12.0 mm, notwithstanding that along with the enlargement of the outer diameter the required flow rate becomes easier to secure, the overall product becomes bulky, leading to a deterioration of the installability into narrow spaces such as under the floor or in the lower engine compartment of an automobile.

[0009] Also, a facing distance between curved top sections that project farthest outward of the curved sections of neighbouring fin members is set to within 0.5 to 5.0 mm. Within the present invention a curved top section means, of a curved section in a fin member that was bendingly formed by the folding of the plate material, the apex standing out farthest in the folding width direction of the fin member. Then, in case of the facing distance being increased beyond 5.0 mm, the necessity arises to arrange neighbouring fin members in the direction of separation, with the pipe member in-between. In consequence, the engagement recesses of the fin members will become shallow, as well as narrow in the axial direction of the pipe member, with a formation length in the direction perpendicular to the axial direction of the pipe member moreover being short, and because it is in these shallow, narrow-width, short-length engagement recesses that the pipe member is engagingly arranged, the contact area between the fin members and the pipe member becomes small such that, together with a decline in heat exchange performance, a worsening of the mounting strength is to be feared.

[0010] On the other hand, in case of the facing distance being set to less than 0.5 mm, the facing distance of neighbouring fin members becomes narrow such that it becomes difficult for stones flipped up from the road surface to enter within this facing distance, such that a situation where a flying stone directly hits the surface of the pipe member during driving becomes unlikely to occur, which is favourable in regard to preventing situations where the pipe member is damaged at its surface by a flying stone forming an indentation, develops stress concentrations due to external forces from vibrations and the like at the indentation, and breaks. However, in order to bring the facing distance below 0.5 mm, the protruding portions of neighbouring fin members have to be arranged side by side with each other, and since the pipe member is situated between the neighbouring fins, arranging both protruding portions side by side demands forming the engagement recesses deeply, in order to engagingly arrange the pipe member in the deep engagement recesses. In consequence, large shear forces that rise in conjunction with the large deformation during the forming of the deep engagement recesses may cause unneeded deformation to occur in the vicinity of the engagement recesses. Within the present invention, facing distance means the arrangement distance of neighbouring fin members, which face each other having the pipe member interposed between them, and in particular means the distance at the curved top sections protruding from the engagement recesses in the fin member width direction, where the pipe member interposed between the fin members does not intervene.

[0011] Also, the height of protrusion of the fin members from the surface of the straight pipe sections of the pipe members is set to 11 mm or less. As for the reason thereof, if the fin members' height of protrusion in the width direction is increased beyond 11 mm the overall product assembled with the fin members becomes bulky such that its installability into automobiles etc. is diminished, while it has become clear from a calculation of the fin efficiency of the fin members, shown below, that a remarkable improvement of the heat exchange performance cannot be expected. Here, the relationship between the height of protrusion of the fin members and the fin efficiency concerning the heat exchange efficiency of the fin members will be explained in the following.

[0012] The calculation was performed using the formula

$$\eta = \tanh(m L) / m L \qquad m \equiv (2 h / k \delta_t)^{1/2} \times L$$

η: fin efficiency (%)
k: thermal conductivity (ca. 150 W/mK for a standard aluminium alloy)
h: heat transfer coefficient (ca. 60 W/m^{2}K perpendicular to the bending plane, ca. 25 W/m^{2}K parallel to the bending plane)
L: height of protrusion of the fin members (mm)
δ_t: sheet thickness of the fin members (0.3 mm)

wherein for the purpose of simplifying calculation the heat exchanger according to the present invention was imaginatively approximated with planar fins that do not possess curved fold-back portions. A graph produced on the basis of this calculation is shown in Fig. 2. While the above fin efficiency means the efficiency of heat dissipation by the fin members, which changes according to the fin member shape, the fin member height, and the fin member sheet thickness, the result in Fig. 2 expresses the condition of change of the fin efficiency where the fin member shape, density, and the sheet thickness of the fin members were held constant, and only the fin member height was varied in the range from 3 mm to 13.5 mm.

[0013] From Fig. 2, it is evident that if the height of protrusion of the fin members in the width direction exceeds 11 mm, the fin efficiency becomes less than 80%, causing the heat exchange efficiency to diminish, whereas setting the height of protrusion of the fin members below 11 mm enables the fin efficiency to be secured at 80% and above, such that the heat exchange efficiency can be satisfactorily maintained. Accordingly, in order to satisfactorily maintain the heat exchange efficiency in the present invention, the height of protrusion of the fin members in the width direction has to be set to 11 mm or less.

[0014] In the context of limiting as aforesaid the height of protrusion of the fin members to 11 mm or less, the present invention sets said height of protrusion of the fin members to a value that, within said range of 0.5 mm to 5.0 mm for the facing distance of the curved top sections, satisfies the formula $y \geqq 2.46\ x^{-0.29}$ (y: height of protrusion of the fin members in the width direction from the pipe member surface / facing distance of the curved top sections, x: facing distance of the curved top sections). This formula has been derived from experiments and simulation analyses as follows.

[0015] First, in order to decide on a shape for the flying stone to be used in the simulation analyses, flying stone tests were performed wherein, together with setting the facing distance *t* of the curved top sections of the fin members to 2.0 mm and the sheet thickness of the fin members to 0.3 mm, the height of protrusion L in the width direction of the fin members was respectively set to 3 mm and 4 mm. These flying stone tests are tests complying with the automotive standard JASO M104 "Testing methods for automobile brake tube" (section: First section, test purpose: Testing method aiming to cause degradation of the organic coating or other exterior surface of the brake tube, Test title: Flying stone test (testing method item No. 5.1)), wherein the testing conditions and testing apparatus according to the standard are chiefly as follows.

(1) air pressure: 0.4±0.03 MPa
(2) blast angle: perpendicular
(3) blast distance: 350 mm
(4) amount of flying stones: 850 g
(5) repetition: 5 times
(6) testing apparatus: gravelometer
(7) flying stones: granite (gravel, size 9 mm to 15 mm)

[0016] Now, whereas the above JASO method standard uses gravel having a smooth surface for the flying stones, in the present flying stone tests, in order to cause larger degradation of the organic coating or other exterior surface to carry out stricter evaluation testing, abrasive media commercially available as abrasive media for general cutting (manufactured by Tipton Corp.: item name "GT", item No. 4) were selected to be used for performing the evaluation. These abrasive media have edge portions, being substantially equilateral triangular columns or substantially equilateral triangular frustrums with a lateral length of about 10 mm and a height of about 8 mm, and are used in practice by some automobile manufacturers for the above flying-stone tests.

[0017] Results of flying-stone tests using the abrasive media are shown in Figs. 3 and 4. Further, Fig. 3(a) is an enlarged plan view photograph of a heat exchanger before a flying-stone test for a case where the height of protrusion *L* in width direction of the fin members was set to 4 mm, and Fig. 3(b) is an enlarged partial plan view photograph of the heat exchanger after the flying-stone test for the case where the height of protrusion *L* in width direction of the fin members was set to 4 mm. Likewise, Fig. 4(a) is an enlarged plan view photograph of a heat exchanger before a flying-stone test for a case where the height of protrusion *L* in width direction of the fin members was set to 3 mm, and Fig. 4(b) is an enlarged partial plan view photograph of the heat exchanger after the flying-stone test for the case where the height of protrusion *L* in width direction of the fin members was set to 3 mm.

[0018] Then, in the case of the height of protrusion in width direction of the fin members being 4 mm, as shown in Fig. 3(b), confirmation by visual inspection of the pipe member surface resulted in that scars due to flying stones were not confirmed. On the other hand, in the case where the height of protrusion in width direction of the fin members had been set to 3 mm, as shown in Fig. 4(b), several scars caused by flying stones were confirmed by visual inspection. These results made clear that, under the condition that the facing distance *t* between the curved top sections of the fin members is 2.0 mm, in case of setting the height of protrusion *L* in width direction of the fin members to 3 mm it becomes easy for flying stones to directly hit the surface of the pipe member, whereas in case of setting the height of protrusion *L* in width direction of the fin members was set 4 mm it hardly occurs that flying stones directly hit the pipe member surface.

[0019] In the above flying-stone tests, the testing was performed for cases where the facing distance t of the curved top sections of the fin members was 2 mm, whereas for other facing distances, simulation analyses about the effect of flying stones were performed according to schematic diagrams based on the aforementioned results. To explain the simulation analyses, at first, schematic diagrams as shown in Fig. 5 were drawn up, based on the above testing results, for the cases where the facing distance *t* of the curved top sections of the fin members was 2 mm, in order to decide on the flying stone shape to be used in the simulation analyses. Further, each schematic diagram in Figs. 5 and 6 is a schematic rendition of a cross sectional view of a heat exchanger, oriented perpendicular to the axial direction of the straight pipe sections of the pipe member. Further, Fig. 5 (a) is a schematic diagram for the case wherein the height of protrusion *L* in width direction of the fin members is 3 mm, and Fig. 5(b) is a schematic diagram for the case wherein the height of protrusion *L* in width direction of the fin members is 4 mm.

[0020] Given the fact that, in the above flying-stone tests, the surface of the pipe member was directly hit by flying stones in the case where the height of protrusion in width direction of the fin members was set to 3 mm, while the pipe member surface was not hit by flying stones in the case where the height of protrusion in width direction of the fin members was set to 4 mm, in the schematic diagrams shown in Fig. 5 the shape of the heat exchanger (20) was schematically represented such that for the case where the height of protrusion *L* in width direction of the fin members was set to 3 mm (Fig. 5 (a)) the flying stone (21) is in a state of touching the surface of the pipe member (1), and for the case where the height of protrusion *L* in width direction of the fin members was set to 4 mm (Fig. 5(b)) the shortest distance *P* between the surface of the pipe member (1) and the flying stone (21) becomes 1 mm.

[0021] From the representation in this way in the schematic diagrams, the shape of the flying stone in the instant of contacting the pipe member surface, as shown in Fig. 5, was decided to be an upturned triangle in the present simulation analyses. Further, in the present simulation analyses, the limit value for the shortest distance between the pipe member (1) and the flying stone (21) in the case wherein the flying stone (21) as shown in Fig. 5(b) does not directly hit the pipe member (1) is set to 1 mm, assuming that if in the schematic diagram the distance between the pipe member and the flying stone is at least 1 mm or more, the pipe member will also not be directly hit by flying stones during actual driving.

[0022] Then, in the same way as for the cases shown in Fig. 5 wherein the facing distance *t* is 2 mm, schematic diagrams as shown in Figs. 6(a) to (d) were prepared and simulation analyses performed for cases wherein the facing distance t is 0.5 mm, 1 mm, 4 mm, and 5 mm, concerning the relationship between each facing distance *t* and the height of protrusion *L* in width direction of the fin members. Within Fig. 6, schematic diagrams are shown for respective cases wherein the facing distance *t* in (a) is 0.5 mm, the facing distance *t* in (b) is 1 mm, the facing distance *t* in (c) is 4 mm, and the facing distance *t* in (d) is 5 mm. Then, from the schematic diagrams of Fig. 6, for each of the aforementioned facing distances *t* a lower bound for the height of protrusion *L* of the fin members was extracted for which the shortest distance between the flying stone (21) and the surface of the pipe member (1) becomes 1 mm, i.e. which prevents flying stones from directly hitting the pipe member.

[0023] As a result, as shown in Figs. 6(a) to (d), the height of protrusion *L* in width direction of the fin members (3) for which the distance between the surface of the pipe member (1) and the flying stone (21) becomes 1 mm, was 1.7 mm for the case of the facing distance *t* being 0.5 mm, 2.5 mm for the case of the facing distance *t* being 1 mm, 7.0 mm for the case of the facing distance *t* being 4 mm, and 8.5 mm for the case of the facing distance *t* being 5 mm. Then, the respective heights of protrusion *L* of the fin members were taken as lower bounds for the height of protrusion of the fin members for which, given the respective facing distances, the surface of the pipe member is not directly hit by flying stones.

[0024] Next, concerning the results from carrying out the above simulation analyses, as shown in Fig. 7, the relationship between the facing distance *t* of the curved top sections of the fin members, and height of protrusion *L* in width direction of the fin member /facing distance *t* of the curved top sections of the fin members, was plotted to be represented as a graph, and from a curve fitted to the plot the formula $y = 2.46\ x^{-0.29}$ (*y*: height of protrusion of the fin members from the surface of the pipe member / facing distance between the curved top sections, *x*: facing distance between the curved top sections) was derived.

[0025] Then, because the higher the height of protrusion in width direction of the fin members is made the farther the surface of the pipe member is positioned towards the interior of the fin members, it can be said that it becomes difficult for flying stones to directly hit the surface of the pipe member if the height of protrusion in width direction of the fin members satisfies the relationship $y \geqq 2.46\ x^{-0.29}$ (*y*: height of protrusion of the fin members from the surface of the pipe member / facing distance between the curved top sections, x: facing distance between the curved top sections). On the other hand, if $y < 2.46\ x^{-0.29}$ (*y*: height of protrusion of the fin members from the surface of the pipe member / facing distance between the curved top sections, *x*: facing distance between the curved top sections) within a range of 0.5 mm to 5.0 for the facing distance of the curved top sections of the fin members, the height of protrusion in width direction of the fin members will become insufficient, such that the distance from the fin members to the pipe member surface will become small, causing direct hits by flying stones to easily occur.

[0026] Furthermore, the fin members may also have a sheet thickness in the range from 0.2 mm to 0.5 mm. If the sheet thickness is set to less than 0.2 mm, due to the fin members becoming thin the heat capacity of the fins will become deficient, which accelerates the temperature fall in the fins such that the heat exchange efficiency is diminished, while at the same time the fin strength is diminished such that it becomes easy for flying stones to come into contact with the surface of the pipe member. Also, if it is made thicker than 0.5 mm, notwithstanding that the strength is raised, material is wasted since with regarding the heat exchange efficiency, while being slightly improved, a remarkable rise cannot be expected.

[0027] Also, the fin members may have an arrangement distance of the fins, which are formed by a folding process, in the range from 1.6 mm to 2.2 mm. The fin arrangement distance means, within the plurality of fin portions formed by the folding process in the fin member, the separation distance between neighbouring individual fins in the pipe axis direction of the straight pipe sections of the pipe member. The numerical range of the fin arrangement distance from 1.6 mm to 2.2 mm is based on the cooling performance test result given below. To explain the cooling performance test, at first, by using fin members comprising an aluminium-alloy fin member sheet thickness of 0.3 mm, among the mechanical properties a tensile strength of 200 MPa, and fin arrangement distances of 1.6 mm, 2.0 mm, 2.3 mm, 3.2 mm, and 4.0 mm, respectively, heat exchangers for each of the respective arrangement distances were produced.

[0028] Then, the respective heat exchangers comprising the different fin arrangement distances were installed in a tubular wind tunnel of rectangular cross section, such as to become parallel to the wind direction (not in the typical way of installing heat exchangers, which is perpendicular) as received when installed in a car, water was passed through the pipe members of the heat exchangers, and the temperature of the water flowing into the heat exchanger as well as the temperature of the water having passed the heat exchanger were each measured. The measurement conditions at the time were as follows.

water inlet temperature	70 °C constant
air stream inlet temperature	20 °C constant
in-pipe water flow rate	1.5 ... 2.5 L/min
air stream velocity	2.5 ... 5.5 m/s

[0029] Then, for each heat exchanger measured at the above measurement conditions, in addition to the inlet temperatures and the outlet temperatures of the water as the pipe fluid and of the air as the fluid between the fins, the respective temperature differences for both temperatures were calculated, the temperature differences were converted into a temperature difference for the case of using light oil instead of water, and the converted temperature differences were taken as the temperature drop of the fluids upon passing the heat exchanger according to the present invention. It should be noted that the conditions when converted were as follows.

light oil inlet temperature	100 °C
air stream inlet temperature	50 °C
light oil flow rate	0.75 L/min
air stream velocity	5 m/s

[0030] Then, the relationship between the temperature drop of the pipe fluid thus obtained for each heat exchanger and the fin arrangement distance of the respective heat exchanger were plotted to be represented in a graph as shown in Fig. 8. It becomes clear from Fig. 8 that within the range from 1.6 mm to 2.2 mm for the arrangement distance, the temperature drop of the pipe fluid exceeds about 10 °C. From this result, because the temperature drop of the pipe fluid due to passing the heat exchanger exhibits high values for fin arrangement distances within the range from 1.6 mm to 2.2 mm compared to other fin arrangement distances, it is preferred to set the fin arrangement distance to the range from 1.6 mm to 2.2 mm in order to maintain a good heat exchange performance. And, if the fin arrangement distance is less than 1.6 mm, while the surface area of the fin members is enlarged, the heat exchange performance is reduced because the arrangement distance becomes too narrow such that the flow regime of the fluid becomes worse due to increases flow restriction, whereas if the arrangement distance is wider than 2.2 mm, while the flow is eased due to diminished flow restriction, the heat exchange performance is reduced also in this case because the surface area of the fin member becomes smaller.

Effect of the Invention

[0031] Because the present invention is configured as stated above, comprising fin members formed as corrugated fins engagingly arranged on a meanderingly formed pipe member, manufacturing is enabled to be made simple, while at the same time it becomes possible to make the surface area of the fin members large, thereby enabling to dissipate efficiently the heat from the pipe member. In addition, forming a heat exchanger according to the configuration and within the dimensional ranges as stated above enables, without compromising the good heat exchange performance, to eliminate the danger that during driving a stone flipped up from the road surface directly hits the surface of the pipe member, thereby damaging the portion of the pipe member that was hit such that an indentation is formed, stress concentration due to external forces from vibration and the like occurs at the indentation, and the pipe member breaks, while furthermore the height of the product in the thickness direction can be made low. For this reason, it becomes possible to achieve a favourable installability into a narrow space such as under the floor of an automobile or the lower engine compartment thereof, particularly at the bottom of an engine front end or the like.

Brief Explanation of the Drawings

[0032]

[Fig. 1] Perspective view showing Embodiment 1 of the present invention.
[Fig. 2] Graph showing the relationship between the height of protrusion in width direction of the fin member and fin efficiency.
[Fig. 3] (a) Enlarged partial plan view photograph showing the state of a heat exchanger before a flying-stone experiment wherein the height of protrusion in width direction of the fin member was set to 4 mm. (b) Enlarged partial plan view photograph showing the state of the heat exchanger after the flying-stone experiment wherein the height of protrusion in width direction of the fin member was set to 4 mm.
[Fig. 4] (a) Enlarged partial plan view photograph showing the state of a heat exchanger before a flying-stone experiment wherein the height of protrusion in width direction of the fin member was set to 3 mm. (b) Enlarged partial plan view photograph showing the state of the heat exchanger after the flying-stone experiment wherein the height of protrusion in width direction of the fin member was set to 3 mm.
[Fig. 5] Schematic diagrams used for a simulation analysis of a facing distance t = 2 between the curved top sections of the fin members.
[Fig. 6] Schematic diagrams used for simulation analyses of a respective facing distance of t = 0.5, 1, 4, 5 between the curved top sections of the fin members.
[Fig. 7] Graph reflecting the relationship between the facing distance of the curved top sections of the fin members, and height of protrusion in width direction of the fin member / facing distance of the curved top sections of the fin members, with a curve fitted thereto.
[Fig. 8] Graph reflecting the relationship between the fin arrangement distance and the temperature drop of the pipe fluid passing through the heat exchanger.
[Fig. 9] Perspective view showing the fin member of Embodiment 1.
[Fig. 10] Enlarged partial cross-sectional view along line A-A in Fig. 1.
[Fig. 11] Enlarged partial cross-sectional view along line B-B in Fig. 1.

Embodiment 1

[0033] To explain Embodiment 1 of the invention, (1) is a pipe member formed of an aluminium alloy, as shown in Fig. 1, wherein a plurality of straight pipe sections (2) is arranged in parallels separated by a fin-member (3) insertion gap (4), ends of the straight pipe sections (2) being curvedly formed such that the curved portions provide U-shaped return bends (5). Through forming the pipe member (1) in this way in meandering fashion, the fin-member (3) insertion gap (4) is formed to line up in preferably multiple instances. Within each insertion gap (4), a respective fin member (3) is engagingly arranged. Furthermore, in the present embodiment, the outer diameter r of the pipe member (1) indicated in Fig. 11 is set to 8 mm. Also, although in the present embodiment, as stated above, the pipe member (1) is formed of an aluminium alloy, in different embodiments it is also possible to form the pipe member (1) from steel, stainless steel, copper, a copper alloy, titanium, a titanium alloy or the like.

[0034] The above-mentioned fin members (3) are formed from an aluminium alloy strip material in flat-sheet form having a sheet thickness of 0.3 mm, through bending the strip material as shown in Fig. 9 into a corrugated shape of uniform folding-wave height as corrugated fins. By providing the fin members (3) in this way as corrugated fins, a large number of fins (7) of flat-board shape, connected by curved sections (6) formed due to the folding process, are integrally formed. Furthermore, in the present embodiment an arrangement distance (18) q of the fins (7), shown in Fig. 10, is set to 2.0 mm. Accordingly, the forming of the fin members (3) as stated above facilitates to arrange a large number of fins (7) in evenly spaced and parallel fashion on the pipe member (1), while the large number of fins (7) and the large number of curved sections (6) enable to make the surface area of the fin members (3) large, such that a product with high heat exchange performance can easily be produced. Also, due to the presence of the curved sections (6) the fin members (3) become three-dimensional, providing an integral structure that is structurally stable, such that the shock resistance improves, and an improvement also of the durability of the heat exchanger (20) is enabled. Furthermore, although in the present embodiment the fin members (3) are formed of an aluminium alloy, in different embodiments it is also possible to form the same from steel, stainless steel, copper, a copper alloy, titanium, a titanium alloy or the like.

[0035] In the fin members (3) formed as stated above, by press-forming curved top sections (15), which of the curvedly formed curved sections (6) project farthest outward, into a recessed shape, arc-shaped engagement recesses (8) as shown in Fig. 9 are formed. As shown in Figs. 10 and 11, in order to enable surface contact with the outer periphery (10) of the pipe member (1), the shape of the engagement recesses (8) is made to correspond to the outer periphery (10) of the pipe member (1).

[0036] Then, in a state where the pipe member (1) is engaged to the engagement recesses (8), as shown in Fig. 1, the fin members (3) are insertingly arranged into the respective insertion gaps (4) with the pipe member (1) on either side. Then, after arranging the fin members (3) as described, both ends and both sides of the pipe member (1), as shown in Fig. 1, are covered respectively by pairs of end cover members (11) and side cover members (12), with both end sections (13) of the pipe member (1) arranged protruding from one of the end cover members (11). Besides, on both sides of the end cover members (11) brackets (14) for mounting the heat exchanger (20) of the present embodiment under a vehicle floor etc. are protrudingly formed.

[0037] The heat exchanger (20) of the present embodiment as stated above, due to comprising a simple configuration wherein fin members (3) that are corrugated fins are engagingly arranged on a pipe member (1), enables to make manufacturing simple, while due to the large surface area of the fin members (3) it becomes possible to dissipate efficiently heat from the pipe member (1), thereby enabling to easily raise the heat exchange performance. Also, as shown in Fig. 1, due to a configuration wherein the fin members (3) are arranged in a row within a single stage, different from the two-stage heat exchanger disclosed in Patent document 1, the height of the heat exchanger (20) in the thickness direction can be made low. This enables the installability into narrow spaces such as under a floor of an automobile to be made favourable.

[0038] Also, since the arrangement distance (18) q of the fins (7) is set to 2.0 mm, it becomes possible, as shown in Fig. 8, to make the temperature drop of the pipe fluid upon passing the heat exchanger (20) high in comparison to other arrangement distances, thereby enabling to obtain a heat exchanger (20) with excellent heat exchange performance. Also, the facing distance (17) *t* of the curved top sections (15) in neighbouring fin members' (3) protruding portions (16) from the pipe member (1) surface is set to 2 mm. Furthermore, the height of protrusion *L* from the pipe member (1) surface in width direction of the fin members (3), shown in Fig. 10, is 4 mm, and in relation to the facing distance (17) *t* = 2 mm of the curved top sections (15) the formula $y \geqq 2.46\, x^{-0.29}$ (*y*: height of protrusion *L* in width direction of the fin members (3) from the surface of the pipe member (1) / facing distance (17) *t* between the curved top sections (15), *x:* facing distance (17) *t* between the curved top sections (15)) is satisfied.

[0039] On the heat exchanger (20) of the present embodiment, prepared as explained above, a flying stone test was performed. The test was carried out according to automotive standard JASO M104 "Testing methods for automobile brake tube", which simulates that during running of an automobile a stone on the road surface is flipped up by a wheel, comes flying and touches. The testing conditions for the flying stone testing on the present embodiment were as follows.

(1) air pressure: 0.4±0.03 MPa
(2) blast angle: perpendicular
(3) blast distance: 350 mm
(4) amount of flying stones: 850 g
(5) repetition: 5 times
(6) testing apparatus: gravelometer (manufactured by Suga Test Instruments Co. Ltd., flying stone testing apparatus JA400)
(7) flying stones: item name "GT", item No. 4 (manufactured by Tipton Corp.: abrasive media having edge portions, for use in cutting, of substantially equilateral triangular column shape or substantially equilateral triangular frustrum shape, with a lateral length of about 10 mm and a height of about 8 mm)

[0040] Then, the surface condition of the fin members (3) and the pipe member (1) after carrying out the flying stone test was visually inspected. The surface condition of the fin members (3) and the pipe member (1) after carrying out the flying stone test is shown in the photographs of Fig. 3. From Fig. 3(b), it could be confirmed, from the fact the individual fins (7) were in contorted condition due to direct impact of flying stones, that the fin members (3) had undergone heavy damage. However, on the surface of the pipe member (1), almost no scars thought to have originated from contact by flying stones could be confirmed. Given such a result, preparation of a heat exchanger (20) with the dimensions of the present embodiment, without compromising good heat exchange performance, enables to prevent damage to the pipe member (1) from flying stones, such that a long product life can be maintained.

[0041] While in the present embodiment no soldering, gluing, painting or the like is performed at the engagement portions (22) of the fin members (3) and pipe member (1), in other differing embodiments close adherence between the fin members (3) and pipe member (1) may be effected by applying soldering, gluing, painting or the like means at the engagement portions (22) and/or the vicinity thereof. By bringing a fin member (3) and the pipe member (1) into close adherence at an engagement portion (22) through the above-mentioned means, situations where openings arise, moisture enters into the openings and the fin member (3) and/or the pipe member (1) corrode can be prevented, enabling an excellent corrosion resistance to be obtained at this engagement portion (22). Also, because the pipe member (1) and the fin member (3) always maintain their state of close adherence, heat exchange between the pipe member (1) and the fin member (3) is enabled to be performed efficiently, such that a further improvement in heat exchange performance becomes possible.

Explanation of Reference Signs

[0042]

1 pipe member

2 straight pipe section

3 fin member

5 return bend

6 curved section

7 fin

8 engagement recess

15 curved top section

16 protruding portion

17 facing distance

18 arrangement distance

Claims

1. A heat exchanger comprising:

a plurality of fin members formed as corrugated fins by folding a sheet material into a corrugated shape, wherein curved sections formed due to the folding are press-deformed into a recessed shape to form engagement sections; and
a meanderingly shaped pipe member including a plurality of straight pipe sections arranged in parallels with the fin members in-between, the straight pipe sections being connected by U-shaped return bends;
wherein in a state in which the straight pipe sections are engaged with the engagement recesses of the fin members, an outer diameter of the pipe member is in the range of 8 mm to 12 mm, and a facing distance between curved top sections that project farthest outward of the curved sections of neighbouring fin members is in the range of 0.5 mm to 5.0 mm, while a height of protrusion of the fin members from a surface of the straight pipe sections is less than or equal to 11 mm and satisfies, within said range of 0.5 mm to 5.0 mm for the facing distance, the formula $y \geqq 2.46\ x^{-0.29}$ (y: height of protrusion of the fin members from the surface of the pipe member / facing distance between the curved top sections, x: facing distance between the curved top sections).

2. The heat exchanger according to claim 1, wherein a sheet thickness is in the range from 0.2 mm to 0.5 mm.

3. The heat exchanger according to claim 1 or 2, wherein a fin arrangement distance is in the range from 1.6 mm to 2.2 mm.

Fig. 1

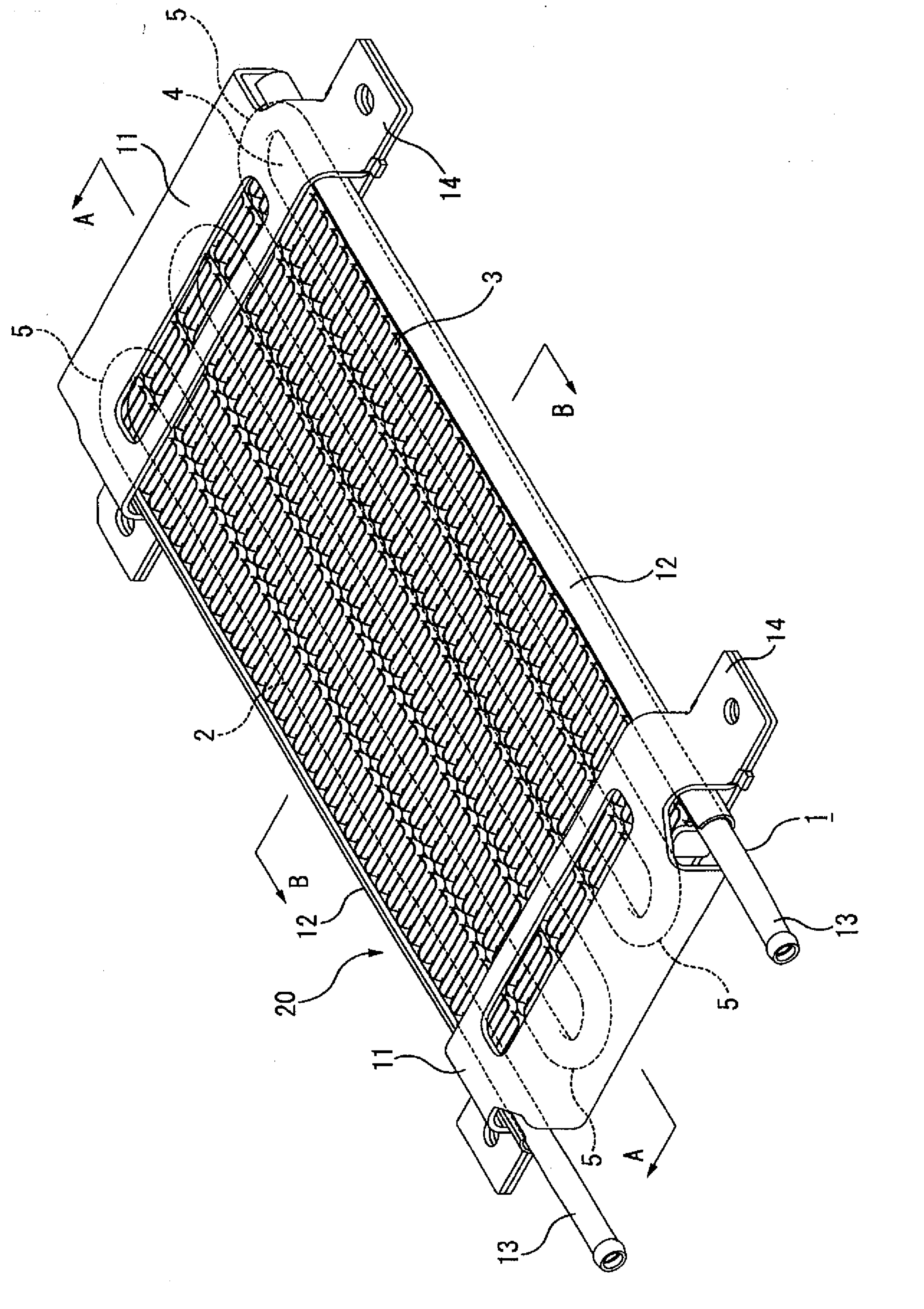


Fig. 2

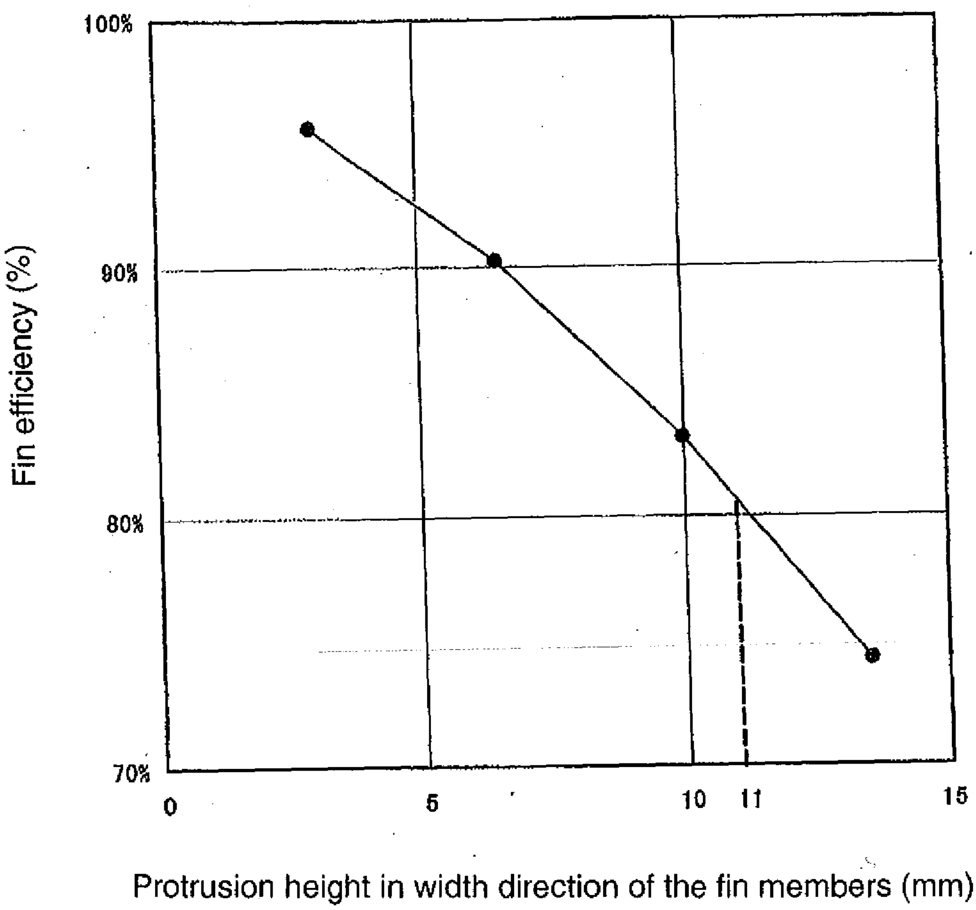
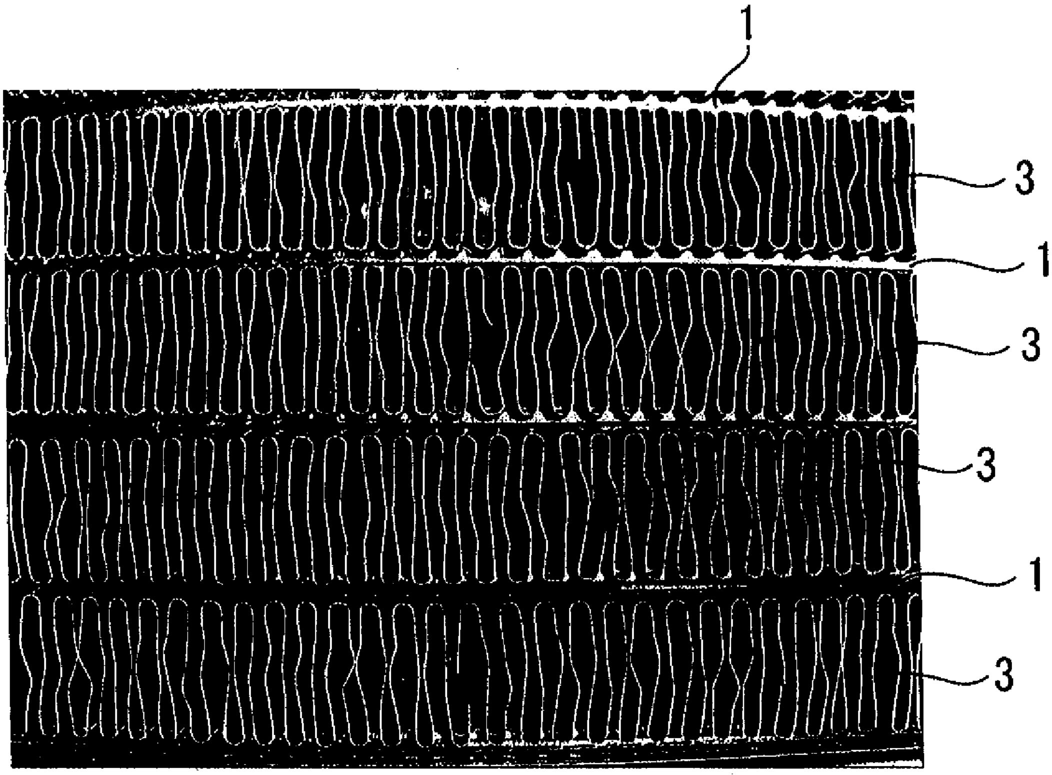

100%
90%
80%
70%
Fin efficiency (%)
0
5
10
11
15
Protrusion height in width direction of the fin members (mm)

Fig. 3

(a)



(b)

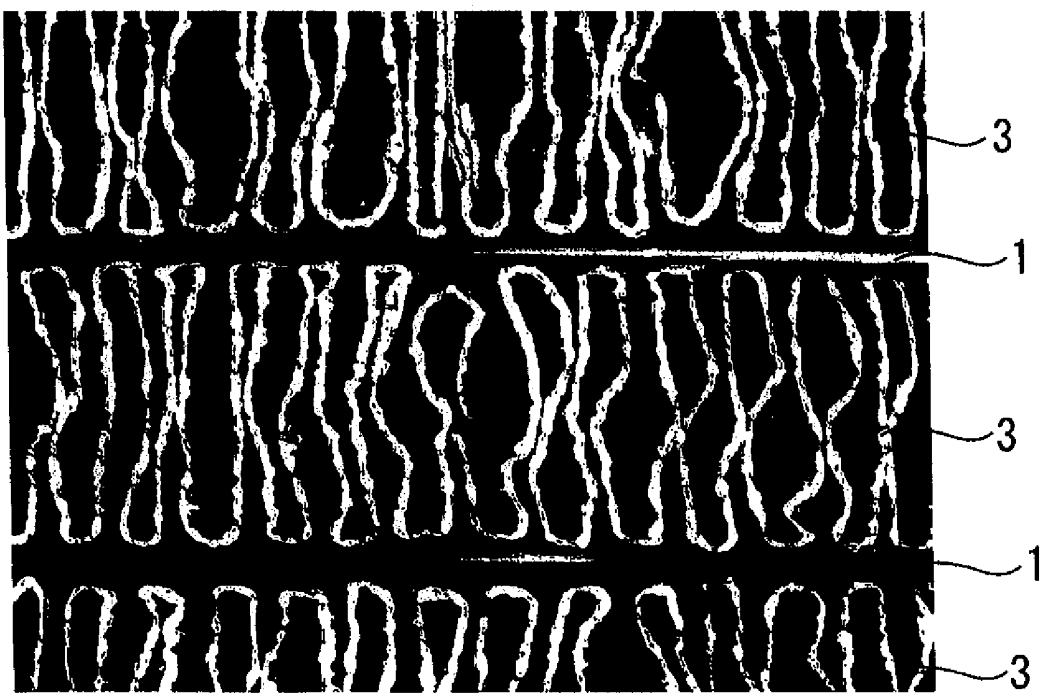
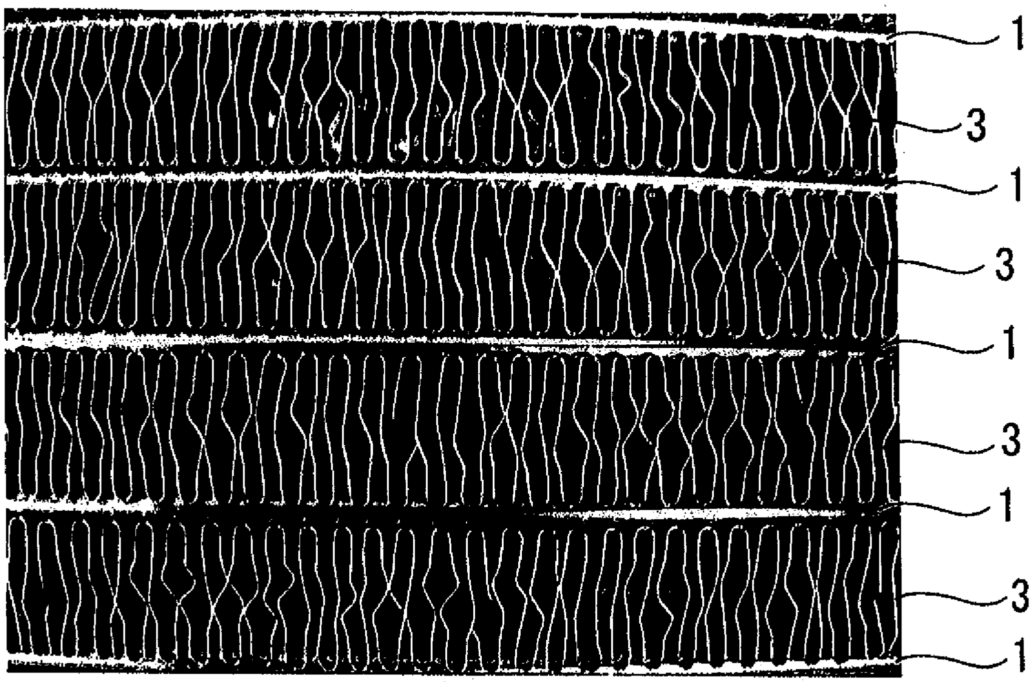


Fig. 4

(a)



(b)

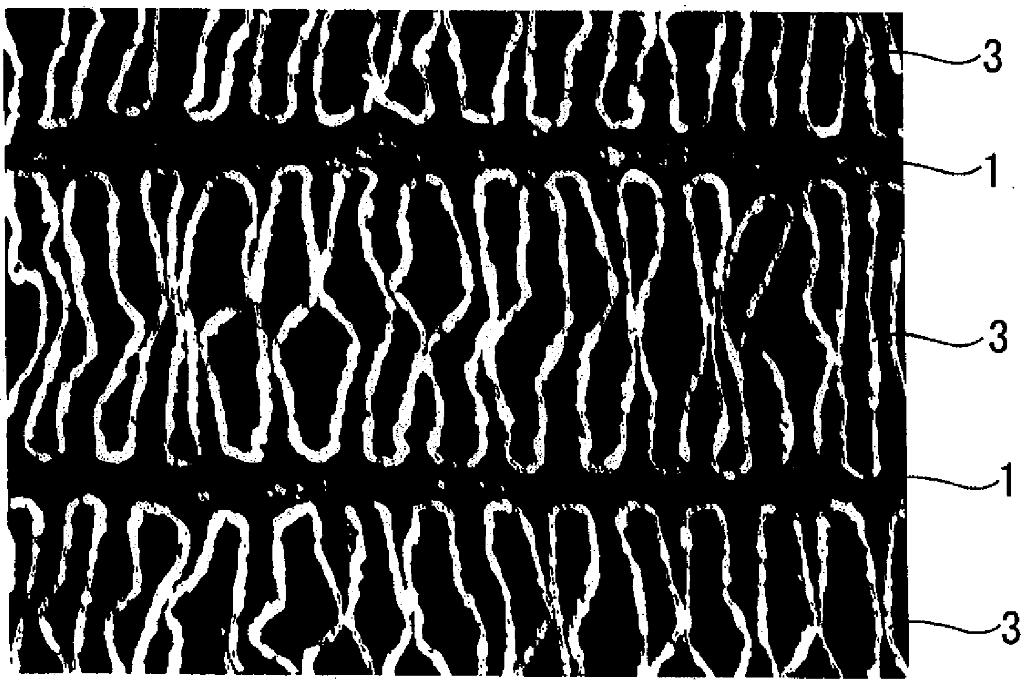
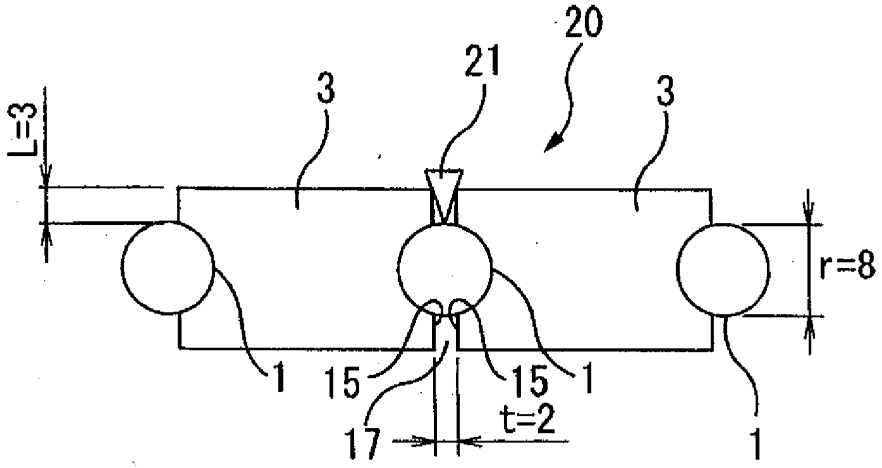


Fig. 5

(a)



(b)

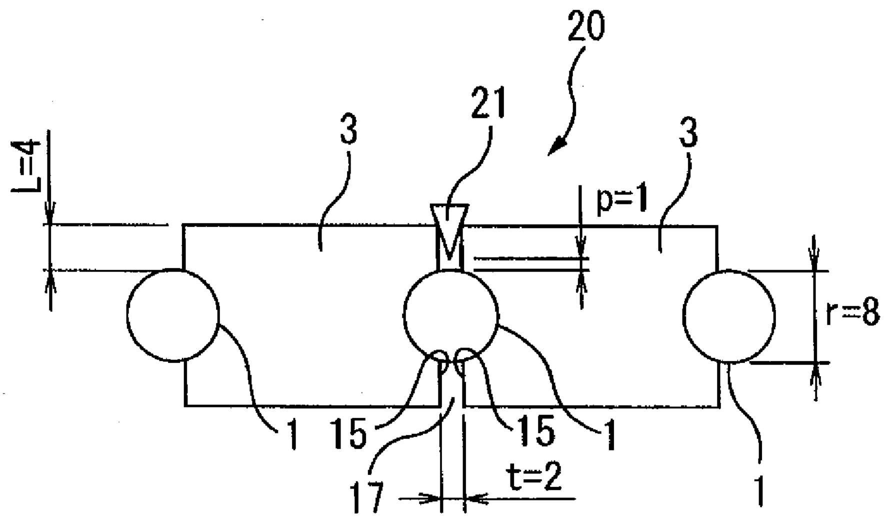


Fig. 6

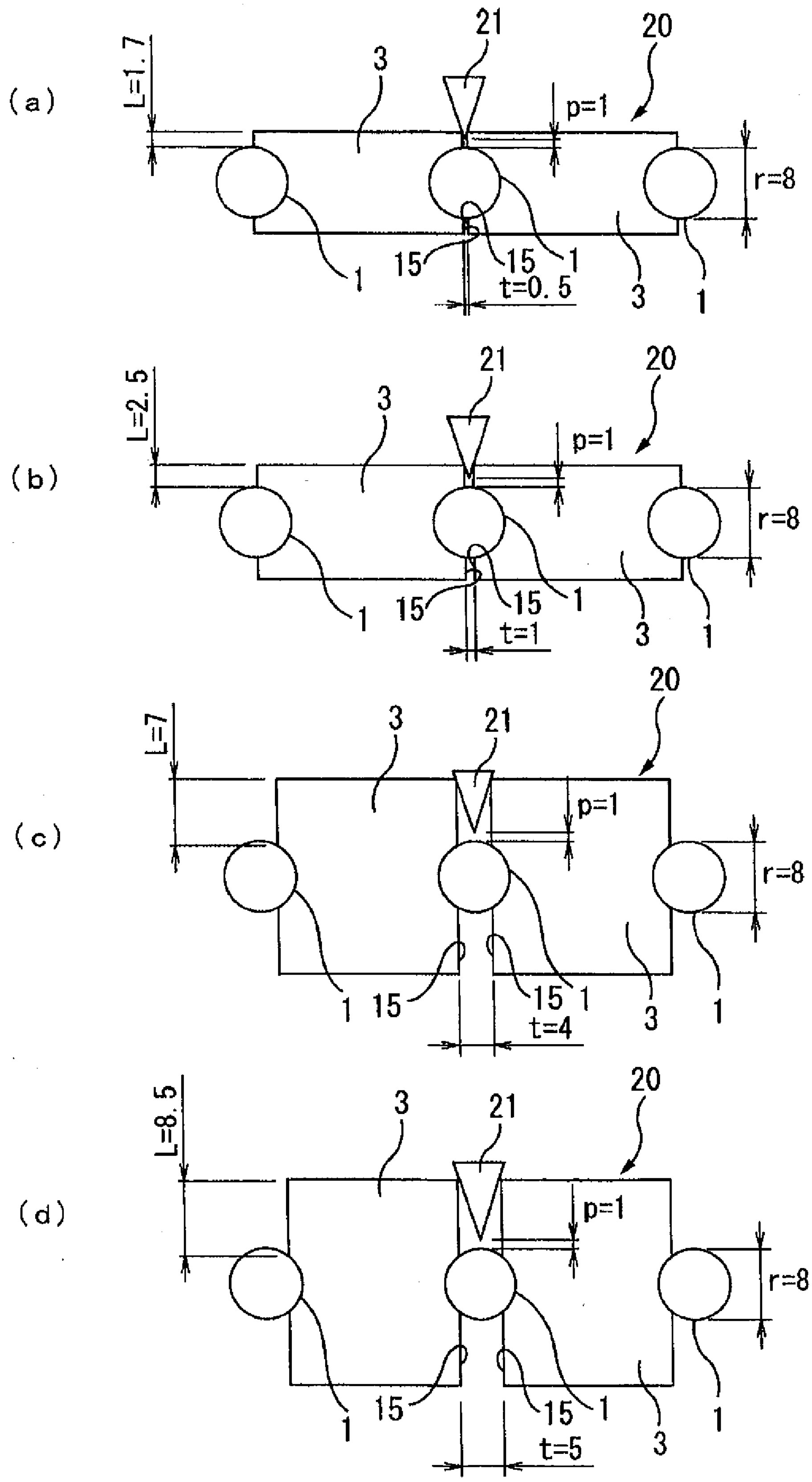

(a)
L=1.7
3
21
20
p=1
r=8
15
15
1
t=0.5
3
1
(b)
L=2.5
3
21
20
p=1
r=8
15
15
1
t=1
3
1
(c)
L=7
3
21
20
p=1
r=8
15
15
1
t=4
3
1
(d)
L=8.5
3
21
20
p=1
r=8
15
15
1
t=5
3
1

Fig. 7

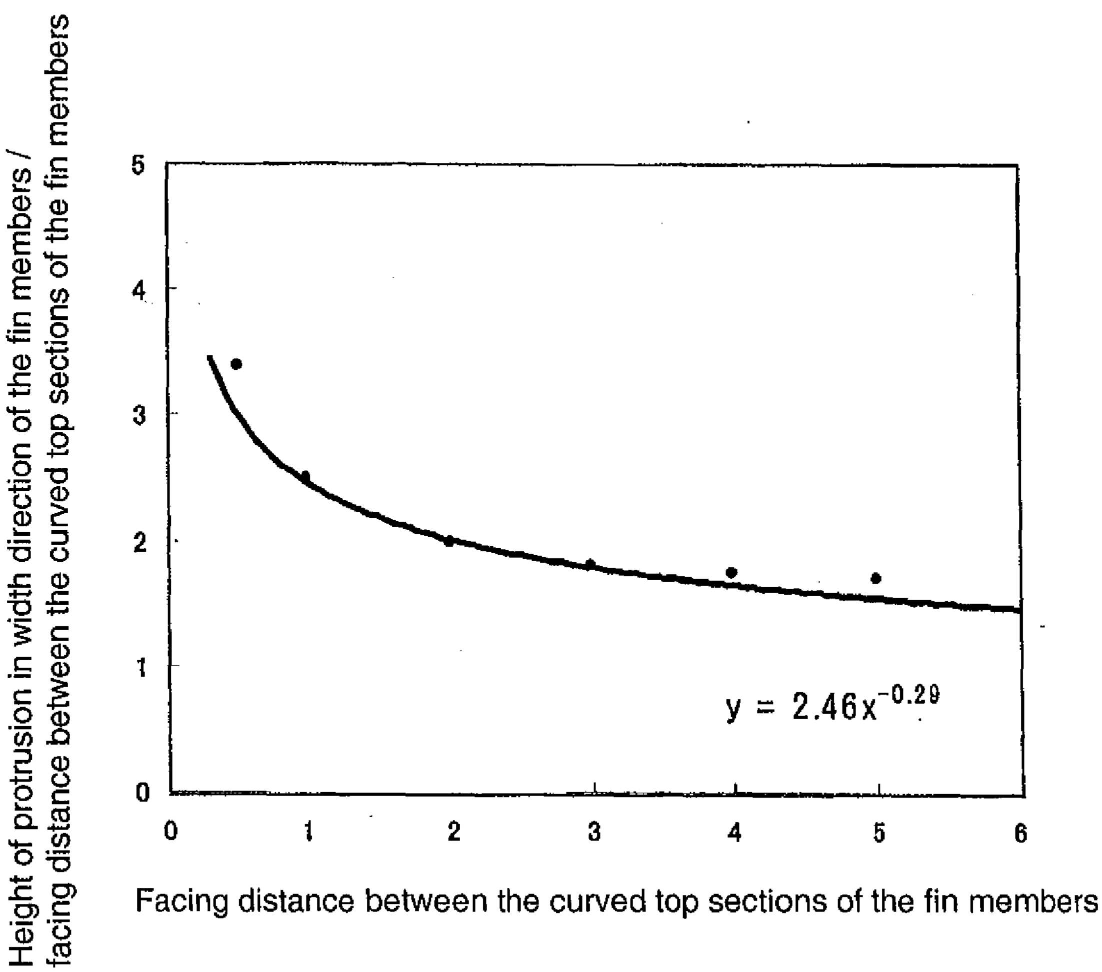

Height of protrusion in width direction of the fin members / facing distance between the curved top sections of the fin members
5
4
3
2
1
0
0
1
2
3
4
5
6
y = 2.46x^-0.29
Facing distance between the curved top sections of the fin members

Fig. 8

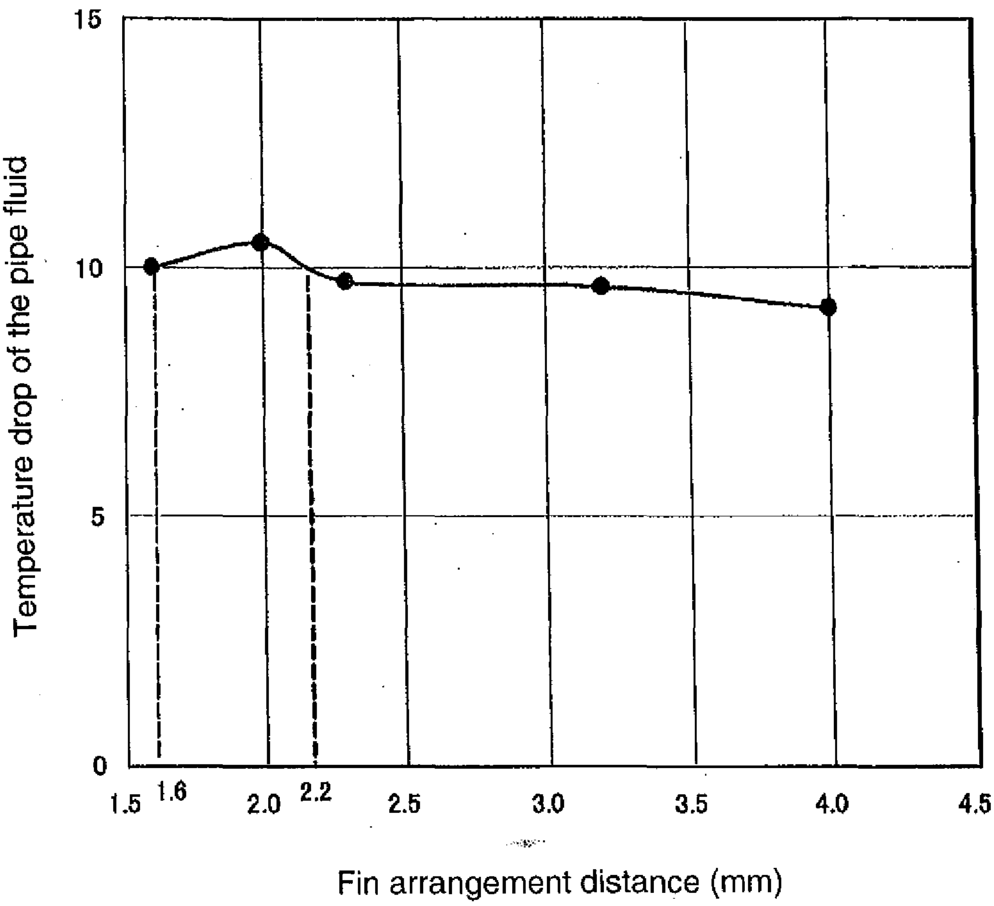

15
10
5
0
Temperature drop of the pipe fluid
1.5
1.6
2.0
2.2
2.5
3.0
3.5
4.0
4.5
Fin arrangement distance (mm)

Fig. 9

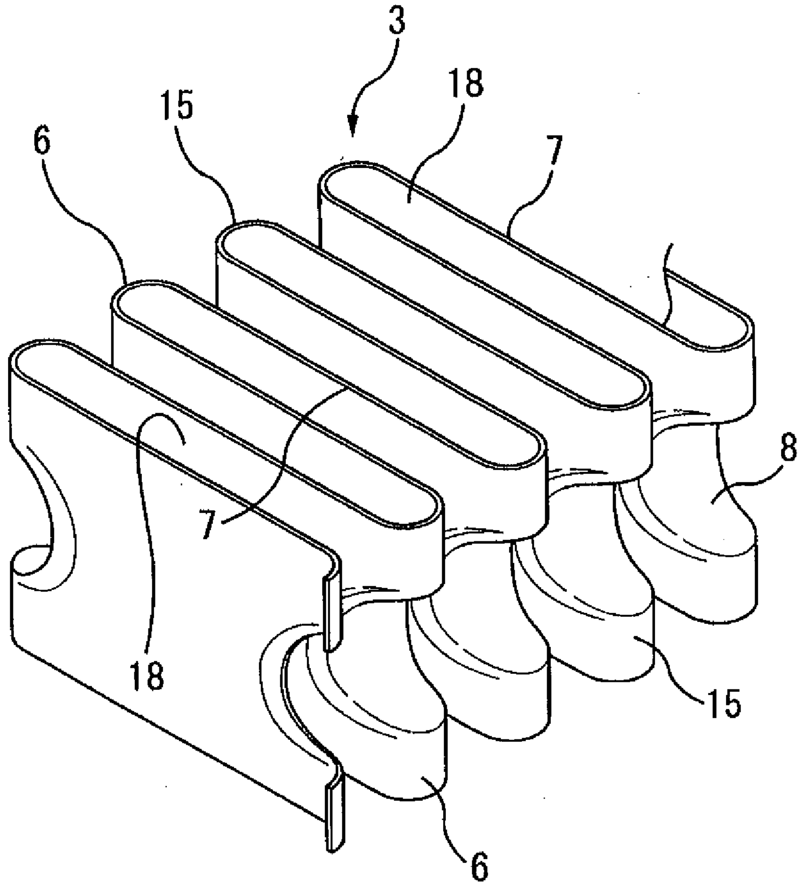


Fig. 10

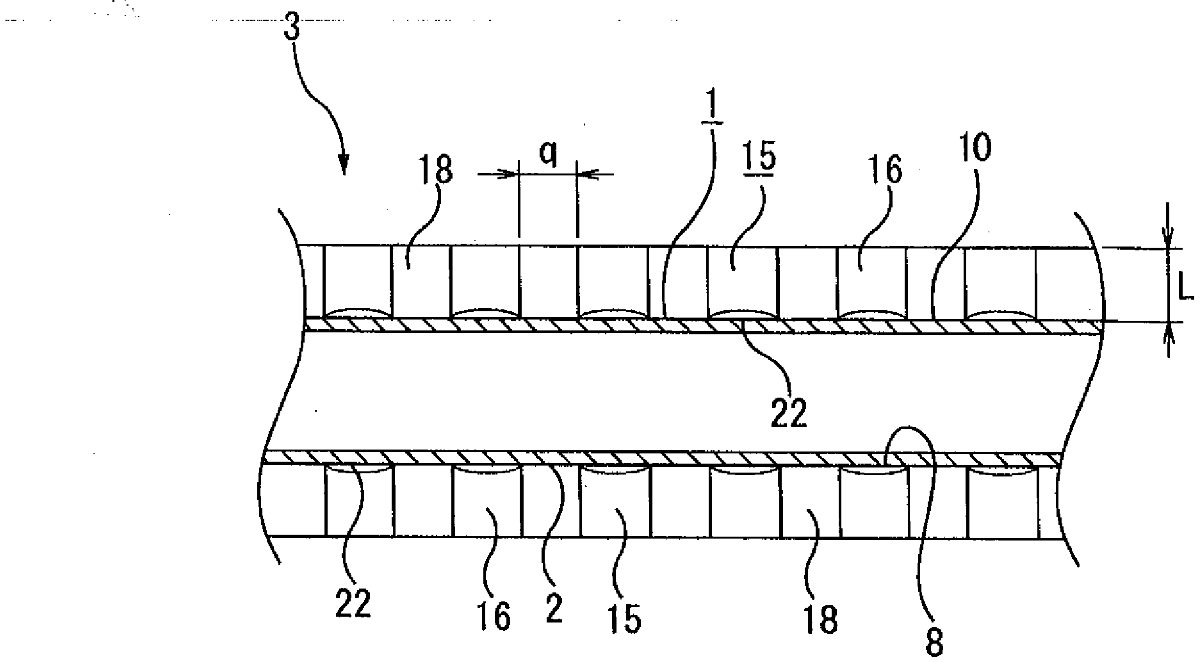
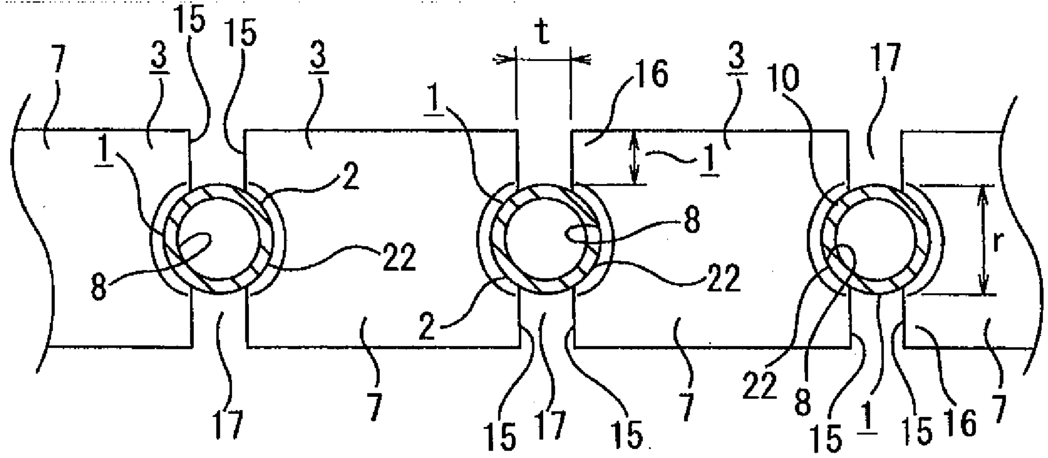


Fig. 11



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/069768

A. CLASSIFICATION OF SUBJECT MATTER
F28F1/30(2006.01)i, *F28F1/32*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F28F1/30, F28F1/32

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2005-201622 A (Usui Kokusai Sangyo Kaisha, Ltd.), 28 July 2005 (28.07.2005), entire text; all drawings & US 2007/0062677 A1 & GB 2424473 A & EP 1696196 A1 & WO 2005/057120 A1 & DE 112004002463 T & CN 1761854 A	1-3

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 November, 2010 (26.11.10)	07 December, 2010 (07.12.10)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2010/069768

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 11-44498 A (Showa Aluminum Corp.), 16 February 1999 (16.02.1999), entire text; all drawings (particularly, paragraphs [0029] to [0032]; fig. 2) & US 6000467 A & US 6289981 B1 & EP 881448 A3 & EP 881448 A2 & DE 69822361 D & DE 69822361 T & AU 6980198 A & CZ 9801696 A & AU 735895 B & AT 262153 T & ES 2216205 T	1-3
A	JP 1-181092 A (Nippondenso Co., Ltd.), 19 July 1989 (19.07.1989), entire text; all drawings (particularly, fig. 1, 2, 5) (Family: none)	1-3
A	JP 6-101982 A (Showa Aluminum Corp.), 12 April 1994 (12.04.1994), entire text; all drawings (particularly, fig. 9) (Family: none)	1-3
A	JP 2000-220982 A (Zexel Corp.), 08 August 2000 (08.08.2000), entire text; all drawings (particularly, fig. 1 to 3) (Family: none)	1-3
A	JP 2009-229025 A (Showa Denko Kabushiki Kaisha), 08 October 2009 (08.10.2009), entire text; all drawings (particularly, paragraphs [0018] to [0031]; fig. 2, 3) (Family: none)	1-3
A	JP 2009-24896 A (Showa Denko Kabushiki Kaisha), 05 February 2009 (05.02.2009), entire text; all drawings (particularly, paragraph [0007]; fig. 2) (Family: none)	1-3

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2005201622 A **[0003]**