

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
28 August 2008 (28.08.2008)

PCT

(10) International Publication Number
WO 2008/103502 A1

(51) International Patent Classification:
F28F 3/00 (2006.01) *F28F 1/02* (2006.01)
F28F 3/02 (2006.01)

(21) International Application Number:
PCT/US2008/050586

(22) International Filing Date: 9 January 2008 (09.01.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
102007008535.6 21 February 2007 (21.02.2007) DE

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

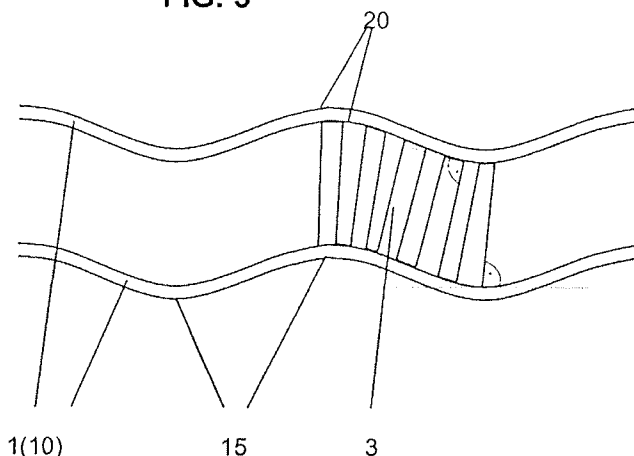
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

(54) Title: HEAT EXCHANGER, METHOD OF MANUFACTURING A HEAT EXCHANGER, AND ROLLER TRAIN FOR MANUFACTURING HEAT EXCHANGER TUBES

FIG. 3



(57) Abstract: The invention relates to a heat exchanger network composed of flat tubes having two narrow sides and two broad sides and having fins arranged between the broad sides of adjacent flat tubes. A medium can flow through at least some of the successive flat tubes in parallel. Another medium can flow approximately transversely thereto as a result of the fins and the two broad sides of the flat tubes having shaped portions in order to influence the flowing in the flat tubes. The heat-exchanging surfaces are enlarged according to the invention by virtue of the fact that the shaped portions are embodied as corrugations, running in the longitudinal direction of the flat tubes, of the broad sides of the flat tubes, and that the corrugations bear at least predominantly against the fins.

**HEAT EXCHANGER, METHOD OF MANUFACTURING A HEAT EXCHANGER,
AND ROLLER TRAIN FOR MANUFACTURING HEAT EXCHANGER TUBES**

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Priority is hereby claimed to German Patent Application No. DE 10 2007 008535.6 filed February 21, 2007, the entire contents of which is incorporated herein by reference.

SUMMARY

[0002] The present invention relates to a heat exchanger network composed of flat tubes having two narrow sides and two broad sides and having fins arranged between the broad sides of adjacent flat tubes. A medium is able to flow through at least some of the successive flat tubes in parallel. Another medium flows approximately transversely thereto as a result of the fins and the broad sides of the flat tubes having shaped portions in order to influence the flow in the flat tubes. In addition, the invention relates to a manufacturing method for flat tubes which are a component of the heat exchanger network. The manufacturing method can be carried out on a roller train. Finally, the invention relates to a roller train with which the manufacturing method for flat tubes can be carried out.

[0003] Heat exchangers which have some of these features have been part of the prior art for a long time. In many cases the shaped portions of the broad sides are composed of local impressions or of projections or the like. Such impressions or projections may be disadvantageous because the connection, often a soldered connection, between the tubes and the fins can be adversely affected, as a result of which the transfer of heat becomes worse. Furthermore, the formation of impressions entails costs.

[0004] Moreover, heat exchangers with heat exchanger networks whose flat tubes are shaped in a serpentine-like manner are part of the prior art. In this context, the relatively long flat tubes have bends through 180°, the fins being arranged between successive bends. In such heat exchangers, medium does not flow through the flat tubes in parallel, in contrast to the heat exchanger networks specified above. Instead, the medium flows, as it were, to and fro in order to pass through the individual flat tube sections between the bends and in order to thus pass from the inlet to the outlet. One example among a large number of other heat exchangers of this type can be found in U.S. Patent No. 4,587,701. Such heat exchanger networks cannot be made as compact as would be desired because of the aforementioned

numerous bends. The compactness is limited because the bending radii cannot be less than a specific lower limit. Excessively small bending radii could close the flat tubes or cause the heat exchanger to become incapable of functioning. These heat exchangers are also often found to have an excessively high pressure loss because of the numerous deflections of the medium flowing in the tubes.

[0005] In addition, there are heat exchangers of what is referred to as the tube bundle design which do not have any heat exchanger networks in the above sense. In these heat exchangers there is a bundle, usually composed of round tubes enclosed in a housing. The wall of the individual tubes can be, for example, shaped in the manner of a spiral or in some other way. One medium flows through the tubes and the other medium flows in and out of the housing, in which case, on the way from the inlet to the outlet, the medium flows through the gaps between the tubes of the bundle. Such heat exchangers usually do not have any fins between the tubes. In addition, these tubes have only wall deformations. These are usually shaped in such a way that the tubes continue to extend linearly.

[0006] Of course, in contrast to this, there are also heat exchangers whose tubes are not linear but rather which are shaped, for example, in the manner of spirals. There may be fins between the individual threads of the worm-like spiral or spirals. However, such construction principles cannot be used, for example, for radiators or the like which are present in a motor vehicle and in which cooling air flows through the fins, at any rate they are not customary in this context.

[0007] One object of the invention is to develop a heat exchanger network design of the type described at the beginning, which is compact, competitive in terms of costs and can also achieve very good values in terms of heat exchanging efficiency.

[0008] With respect to the heat exchanger network of the present invention there is provision for the shaped portions to be embodied as corrugations, running in or approximately in the longitudinal direction of the flat tubes, of the broad sides of the flat tubes, and for the corrugations to bear at least predominantly against the fins. The narrow sides of the flat tubes also have the corrugations since they are part of the same flat tubes. The corrugations of the broad sides and of the narrow sides oscillate progressively about an imaginary plane which lies in the broad sides (not yet corrugated). In contrast, the corrugations of the narrow sides in the preferred exemplary embodiment do not oscillate

about another plane which is perpendicular to the aforesaid plane, that is to say about a plane which lies in the narrow sides. Such a corrugation formation of the narrow sides is extremely difficult for flat tubes in terms of fabrication technology and is therefore not preferred in the present context. The heat exchanger network can have all types of flat tubes, those which have been manufactured, for example, in an extrusion method or those which have been manufactured, for example, as welded flat tubes, or those which have been manufactured according to the manufacturing method described below. In the proposed heat exchanger network, these last-mentioned flat tubes are preferably used because they can be equipped with an extremely small wall thickness owing to the manufacturing method.

[0009] A network which is developed according to the invention has a better heat exchanging efficiency because the heat-exchanging surfaces are enlarged. The heat exchanger network according to the proposal can, completely without problems, be made precisely as compact as what is referred to as a high-performance cooling network from the prior art, which has flat tubes without corrugations. The manufacturing costs are competitive in all cases, in particular if the fact that the wall thickness of the flat tubes has been drastically reduced is taken into account.

[0010] Because the corrugations are preferably flat corrugations which correspondingly have relatively large corrugation lengths and comparatively small corrugation heights, the pressure loss varies within very moderate ranges. The pressure loss can be influenced by the corrugation geometry.

[0011] It is provided that the parallelism of the two broad sides of each flat tube be essentially retained by the corrugations. It is further preferably provided that the parallelism of the arrangement of the flat tubes which is known in the prior art is essentially retained after the corrugation.

[0012] Moreover, it is preferably provided that the broad sides are, with the exception of the corrugations, otherwise planar, that is to say they do not have any local impressions or projections. For this reason, despite the corrugations, good soldering results between the flat tubes and the fins are achieved.

[0013] In particular it is provided that the flat tubes be capable of being manufactured from at least one continuous, shaped sheet metal strip on a roller train or on a fabrication line and that the two narrow sides of the flat tubes be reinforced.

[0014] In order to be able to make a decisive contribution to further increasing the heat exchanging efficiency, it is further provided that the wall thickness of the flat tubes or the thickness of the at least one sheet metal strip be in the range from 0.03 mm - 0.20 mm.

[0015] The manufacturing method for flat tubes, which are a component of a heat exchanger network and which are manufactured from at least one strip of continuous ribbon-shaped material with at least one wall part and one inner part which is embodied with corrugations, on a roller train which is equipped with pairs of rollers, the strip running through the rollers in the longitudinal direction and being shaped, the inner part which is embodied with corrugations being placed between the shaped wall part, after which the flat tube is closed and finally individual flat tubes are cut to length, provides according to the invention that after the closing and before the cutting to length the broad sides of the flat tubes are provided with a corrugation which runs in the longitudinal direction of the flat tubes. The method ensures economic manufacture of the flat tubes with a very small wall thickness and in large numbers. The corrugations of the inner part result in flat tubes which have ducts running in their longitudinal direction. The ducts can be discrete ducts or else ducts which have a flow connection with one another.

[0016] With respect to the roller train for carrying out the method for manufacturing flat tubes composed of at least one continuous strip of ribbon-shaped material, the roller train having at least one section for shaping the strip, a section for joining the strip to the tube and a cutting station for tubes, it is provided according to the invention that a shaping station with which it is possible to manufacture a corrugation running in the longitudinal direction of the flat tubes, on the broad sides of the flat tubes, be arranged between the joining section and the cutting station.

[0017] In order to produce the heat exchanger network composed of the flat tubes and the fins, said flat tubes and fins are, as is known, stacked and loaded with appropriate pressure forces. The necessary pressure forces are somewhat larger than in heat exchanger networks from the prior art. For this purpose, the inventor has found that it is significantly more favorable to use what are referred to as flat-top fins as fins. These are likewise corrugated fins whose corrugation summits and corrugation valleys are, however, made flat, in contrast to corrugated fins with rounded corrugation summits and corrugation valleys. Such flat-top fins fit more snugly into the broad sides of the flat tubes which are formed with corrugations when the heat exchanger network is pressed together, and they therefore give better soldering

results. However, a certain degree of know-how is necessary here, also in terms of the aspect of the two broad sides of each flat tube being spaced apart only by approximately 1 - 2 mm in certain exemplary embodiments. The aforesaid pressure forces must on the one hand be large enough for the fins to fit snugly into the corrugations. On the other hand, the contact pressure forces must not lead to the two broad sides of the flat tubes being pressed in or the flat tube closing where possible. In this context, the preferred flat tube which is manufactured according to the manufacturing method and has a corrugated inner part can be considered advantageous because the corrugated inner part can prevent the flat tubes from collapsing or can at least counteract collapsing. The pressure forces are preferably applied with pressure elements (auxiliary devices) whose surface is also embodied with corrugations, in which case the corrugations in the pressure elements should correspond to the corrugations of the flat tubes.

[0018] The thickness of the ribbon from which the fins are manufactured is also in the range from 0.03 - 0.09 mm. When the premounting process of the heat exchanger network is ended, the heat exchanger networks are subject to a soldering method, usually a CAB soldering method. Here, both the individual flat tubes and the flat tubes with the fins are soldered securely. This is understood to mean that corresponding solder coatings and further requirements have to be present. The material is particularly preferably aluminum or an aluminum alloy. However, it is readily apparent that other solderable metals are likewise suitable.

[0019] Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Figures 1 and 2 show respectively an unshaped flat tube and a flat tube which is formed with corrugations according to some embodiments of the present invention.

[0021] Figure 3 shows a portion of a heat exchanger network according to Figure 4.

[0022] Figures 5 and 6 show the formation of corrugations.

[0023] Figures 7 and 8 show a moment during the manufacture of the heat exchanger network.

[0024] Figures 9 and 10 show a preferred flat tube.

[0025] Figure 11 is a diagrammatic representation of a roller train according to some embodiments of the present invention.

DETAILED DESCRIPTION

[0026] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of “including,” “comprising,” or “having” and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Unless specified or limited otherwise, the terms “mounted,” “connected,” “supported,” and “coupled” and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, “connected” and “coupled” are not restricted to physical or mechanical connections or couplings.

[0027] The flat tubes of the heat exchanger network are manufactured on a roller train or fabrication line which is illustrated in a basic form in Figure 11. In this exemplary embodiment, the flat tubes are manufactured from “continuous” sheet-metal ribbons. Furthermore, there are other exemplary embodiments which are not shown and in which the flat tubes are manufactured from a single sheet-metal ribbon or from two sheet-metal ribbons. At this point the applicant refers to the following earlier German Patent Application Nos. DE 10 2006 006 670.7, DE 10 2006 041 270.2, DE 10 2006 002 789.2, and DE 10 2006 035 210.6, all of which are hereby incorporated by reference. In these earlier applications flat tubes composed of a single sheet-metal ribbon or of two sheet-metal ribbons are described and shown. The flat tubes are suitable in the same way to be used in the heat exchanger network, for the exemplary embodiment present here in which one wall part **a** of the flat tube is produced from one sheet-metal ribbon and the other wall part **b** of the flat tube is produced from the second sheet-metal ribbon, and the inner part **c** is produced from the third sheet-metal ribbon. Figure 10 shows a completed flat tube in cross section, and Figure 9 shows a situation in the course of manufacture of the flat tubes, specifically the situation

which is present for example in the joining section **V** of the roller train in which the inner part **c** is placed between the two wall parts **a**, **b**.

[0028] Figures 9 and 10 also show that the two wall parts **a** and **b** are of substantially identical design. They have a relatively large curve at one of their edges, and have a smaller curve on their other edge. In the moment shown in Figure 9, the smaller curves have already been completed and the larger curves are already preformed. The inner part **c** is firstly provided obliquely between the two wall parts **a**, **b**, and the wall parts **a**, **b** are moved toward one another and the flat tube is closed by positioning the two larger curves around the smaller curves, as a result of which the narrow sides **10** of the flat tube are formed. As a result, a double wall thickness, which constitutes the aforementioned reinforcement of the narrow sides **10**, is produced in the narrow sides **10**. As Figure 10 shows, the narrow sides **10** can also be reinforced by virtue of the fact that the two longitudinal edges of the inner part **c** bear in the narrow sides **10**. The longitudinal edges of the inner part **c** can, as is apparent, also be shaped with a small curve for this purpose. The wall thickness of the two wall parts **a**, **b** can be in the range from 0.03 mm - 0.20 mm or 0.15 mm. The wall thickness of the inner part **c** is preferably in the range from 0.03 mm - 0.09 mm. As a result of the provision of the corrugated inner part **c**, the flat tube has ducts **30** which extend in the longitudinal direction and can be seen in the cross section according to Figure 10.

[0029] Figure 11 also shows that, for individual flat tubes, a shaping station **W** with which corrugations **15** running in the longitudinal direction **LR** of the flat tube **1** are formed on the broad sides **20** is positioned between the already mentioned joining station **V** and the cutting station **A** arranged at the end of the roller train. A possible embodiment of the shaping station **W** is illustrated in principle in Figure 5. It is composed of three pairs of rollers. The first pair of rollers in the running direction or in the longitudinal direction of the flat tube is rigid, that is to say it is composed of two centrally mounted rotating rollers between which the continuous flat tube runs and it keeps the latter at the predefined height level. The pair of rollers which follows directly is embodied in the manner of wobble plates with off-center axes of rotation. The rotation of this pair of rollers leads to an oscillating movement of the gap between the two rollers in which the flat tube runs, as a result of which the corrugations are formed. The third pair of rollers also makes the oscillating movements. In the exemplary embodiment according to Figure 6 which is shown as an alternative to this, three pairs of rollers with central axes of rotation for manufacturing the corrugations are

present. The first pair of rollers is also of rigid construction here. The central pair of rollers and the last pair of rollers can be moved vertically, that is to say that they also carry out oscillating movements (double arrows), as a result of which the corrugations can be manufactured.

[0030] Figure 1 shows a short detail of a flat tube which has not yet been provided with corrugations, as a view on one of the narrow sides **10** of the flat tube. Figure 2 shows the same view of a flat tube in which the corrugations **15** are already formed. The dashed line shows the center plane of the flat tube about which the corrugations **15** oscillate progressively. As Figure 2 can indicate, the corrugations **15** in the exemplary embodiment shown are formed with significantly larger corrugation lengths than amplitudes (corrugation heights), for which reason the corrugations **15** are rather flat. The corrugations **15** preferably run in the longitudinal direction **LR** of the flat tube. However, they can also have a small angle in their running direction with respect to the longitudinal direction **LR**, which is intended to be expressed by the choice of words “approximately in the longitudinal direction **LR**”. The term “running direction of the corrugations” is intended to signify a direction which is perpendicular to the edges of the corrugations, as it were the direction of flow in the waves of a liquid.

[0031] Figure 4 shows a view of a heat exchanger network composed of flat tubes **1** and fins **3**, and Figures 7 and 8 show the manufacture of the network with sufficient clarity. In all these illustrations, only one of the narrow sides **10** of the flat tubes **1** can be seen. These are therefore views in the direction of flow of the cooling air. The cooling air flows through the corrugated fins **3** in the direction of the depth (not indicated) of the cooling network. In addition, the illustration shows that the running direction of the corrugations of the corrugated fins **3** lies in the running direction of the corrugations **15** of the broad sides of the flat tubes. The individual flat tubes **1** which are cut to size and are formed with the corrugations **15** are then stacked alternately with corrugated fins **3** of the flat-top design. An auxiliary device **50** can be used, as shown in Figures 7 and 8, to press the network, the flat tubes **1** and the fins **3** together. The auxiliary device **50** is also provided with a corrugation **51** which should correspond approximately to the corrugation **15** of the flat tubes **1**.

[0032] Figure 3 shows an enlarged detail of the network in which it is possible to see that the design of the fins **3** which is used fits more snugly against the broad sides **20** of the corrugated flat tubes **1** than would be possible for corrugated fins **3** with rounded corrugation

summits and corrugation valleys. The geometry of the flat-top fins is changed somewhat by the pressing process, which is also apparent from a comparison of Figures 7 and 8. The individual edges of the fins **3** assume, under the effect of the forces, a position approximately perpendicular to the surface of the corrugated broad sides **20**. The otherwise often criticized disadvantage of flat-top fins easily bending is converted to an advantage here. In the state according to Figure 8, the soldering process of the heat exchanger network is carried out (not shown). The fins **3** are manufactured from aluminum ribbon-shaped material with a thickness 0.03 mm - 0.09 mm. The rib height **h** (Figure 7) is approximately between 3 mm - 9 mm or somewhat more. The flat tubes have, for example for an individual application as a radiator, a small dimension **d** (Figure 9) of not much more than 1.0 mm, for which reason the tubes **1** and fins **3** can be arranged in a very compact fashion. The use of the aforementioned small sheet-metal thicknesses and rib heights permits more tubes **1** and fins **3** to be arranged in the same installation space, which proves advantageous as it enlarges the heat-exchanging surfaces. From Figure 3 it is also clear that the parallelism of the two broad sides **20** of each flat tube **1** is essentially retained by virtue of the corrugations **15**. In addition it is apparent that the parallelism of the arrangement of the flat tubes **1** in the network is essentially retained after they have been corrugated.

[0033] The embodiments described above and illustrated in the figures are presented by way of example only and are not intended as a limitation upon the concepts and principles of the present invention. As such, it will be appreciated by one having ordinary skill in the art that various changes in the elements and their configuration and arrangement are possible without departing from the spirit and scope of the present invention as set forth in the appended claims.

CLAIMS

What is claimed is:

1. A heat exchanger network comprising:
a plurality of flat tubes, each of which has two narrow sides and two broad sides; and
fins arranged between the broad sides of adjacent flat tubes, a medium being able to flow through at least some of the successive flat tubes in parallel, an other medium flowing approximately transversely thereto as a result of the fins;
the two broad sides of each of the plurality of flat tubes having corrugations running approximately in a longitudinal direction of the broad sides of the flat tubes in order to influence flow through the flat tubes, the corrugations bearing at least predominantly against the fins.
2. The heat exchanger network according to claim 1, wherein parallelism of the two broad sides of each flat tube is essentially retained by the corrugations.
3. The heat exchanger network according to claim 1, wherein parallelism of the arrangement of the flat tubes in the network is essentially retained.
4. The heat exchanger network according to claim 1, wherein the broad sides do not have any local impressions or projections.
5. The heat exchanger network according to claim 1, wherein the flat tubes are manufactured from at least one continuous, shaped sheet metal strip on a roller train, and wherein the two narrow sides of the flat tubes are reinforced.
6. The heat exchanger network according to claim 5, wherein the thickness of the at least one sheet metal strip is in the range between 0.03 mm and 0.15 mm.
7. The heat exchanger network according to claim 5, wherein the narrow sides are at least twice as thick as the broad sides.

8. The heat exchanger network according to claim 1, wherein the fins have substantially flat corrugation summits and corrugation valleys.

9. The heat exchanger network according to claim 1, wherein the corrugations of the corrugated fins extend in a direction between the broad sides of the flat tubes.

10. The heat exchanger network according to claim 1, wherein a height of at least one of the fins and the corrugations is approximately between 3.0 and 9.00 mm.

11. The heat exchanger network according to claim 1, wherein a thickness of the fins is approximately in the range between 0.03 mm and 0.09 mm.

12. A method of manufacturing flat tubes for a heat exchanger network from at least one strip of continuous ribbon-shaped material, the tubes having at least one wall part and one corrugated inner part, the method comprising the acts of:

- providing a roller train having a pair of rollers;
- running the strip through the pair of rollers in a longitudinal direction;
- shaping the inner part and placing corrugations between the shaped wall part;
- closing the flat tube; and

cutting a plurality of individual flat tubes to length, wherein after the flat tube is closed and before the plurality of individual flat tubes are cut to length, broad sides of the flat tubes are provided with a corrugation which runs in a longitudinal direction of the flat tubes.

13. A roller train for manufacturing flat tubes composed of at least one continuous strip of ribbon-shaped material, according to the method of claim 12, the roller train comprising:

- at least one section for shaping the strip;
- a section for joining the strip to a tube;
- a cutting station for tubes; and

a shaping station with which it is possible to manufacture a corrugation running in the longitudinal direction of the flat tubes on the broad sides the flat tubes, the shaping station being arranged between the joining section and the cutting station.

14. The roller train according to claim 13, wherein the shaping station contains at least one pair of rollers which operates according to the principle of wobble shafts.

15. The roller train according to claim 14, wherein the wobble shaft pair of rollers interacts with another pair of rollers.

16. The roller train according to claim 13, wherein the shaping station comprises three pairs of rollers, two pairs of rollers of which can be moved in order to be able to form the corrugation.

FIG. 1

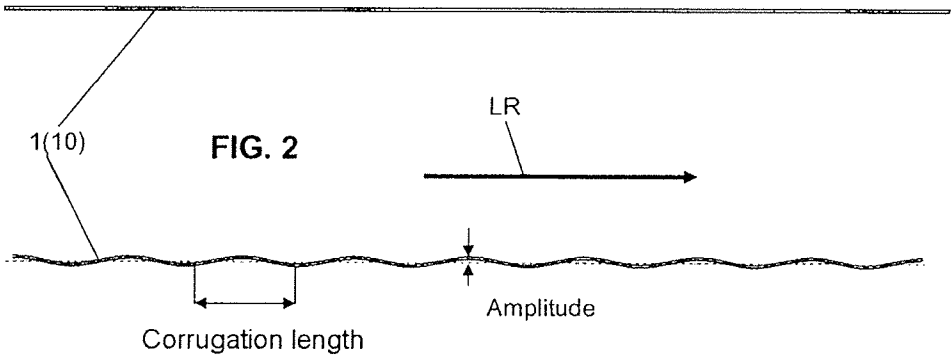
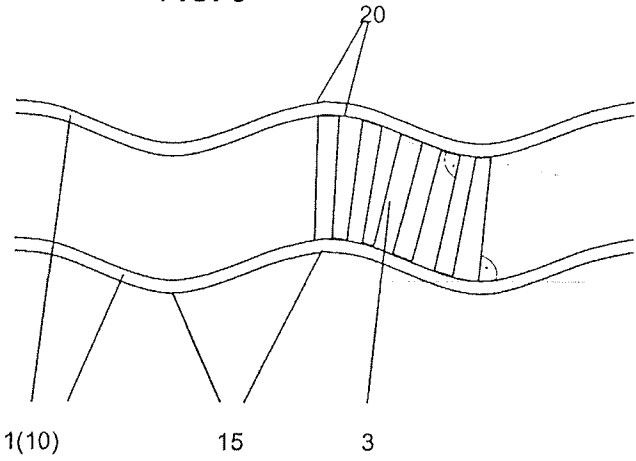


FIG. 3



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FIG. 4

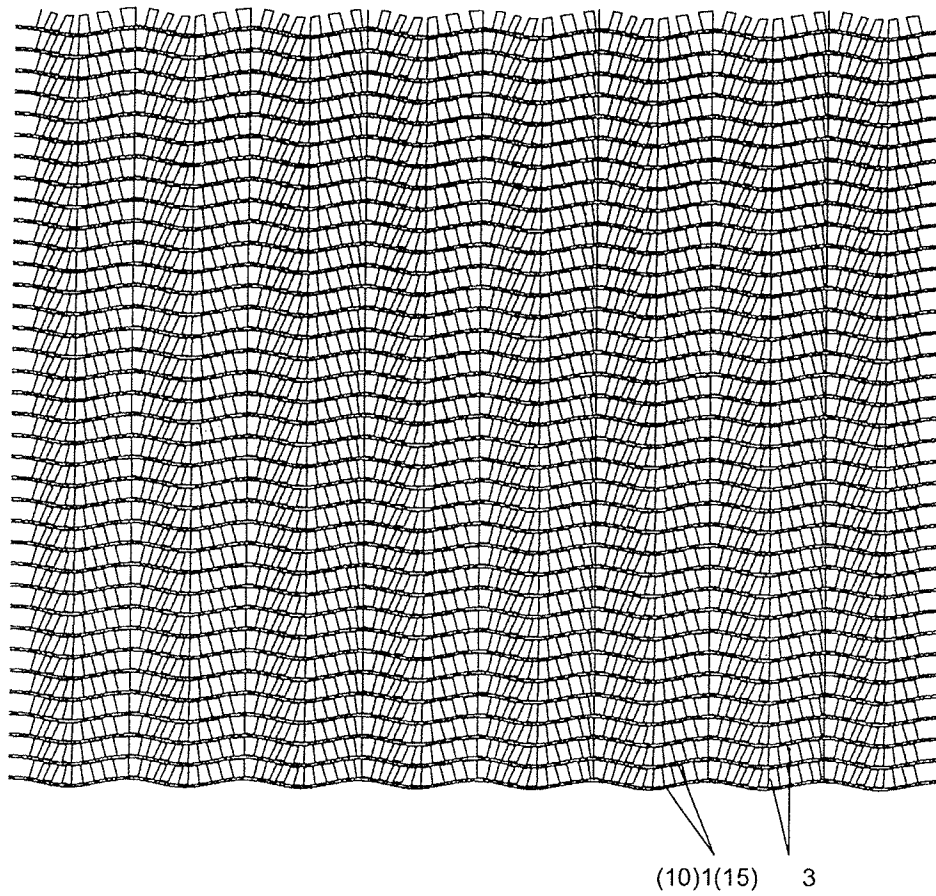


FIG. 5

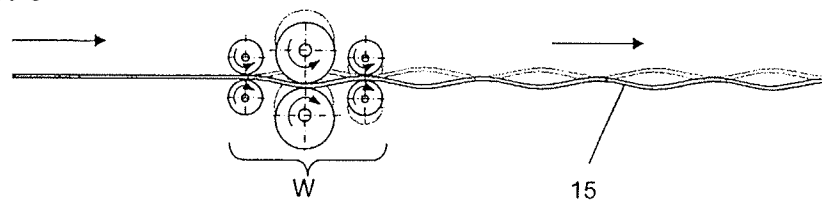
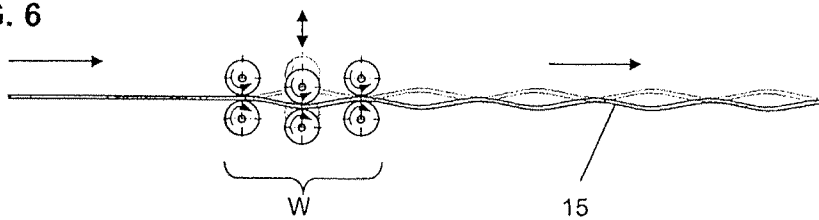


FIG. 6



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FIG. 7

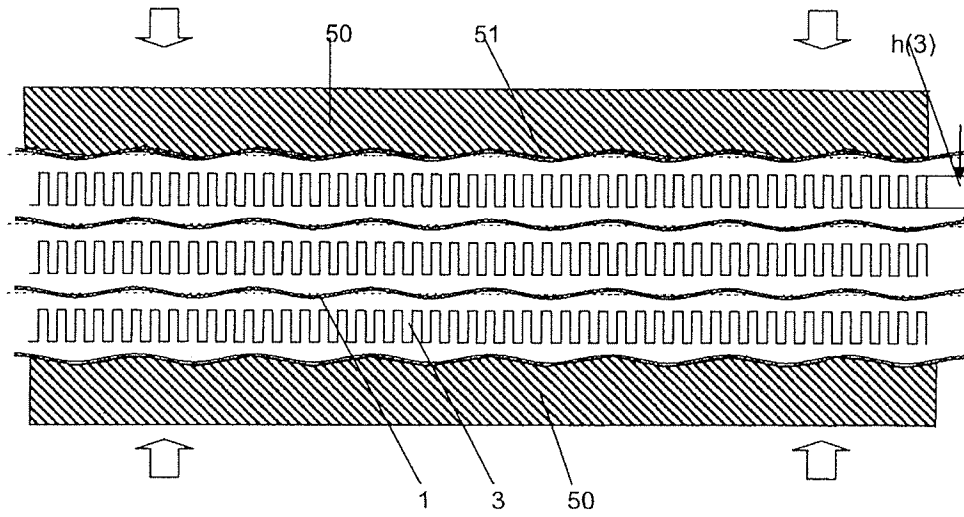
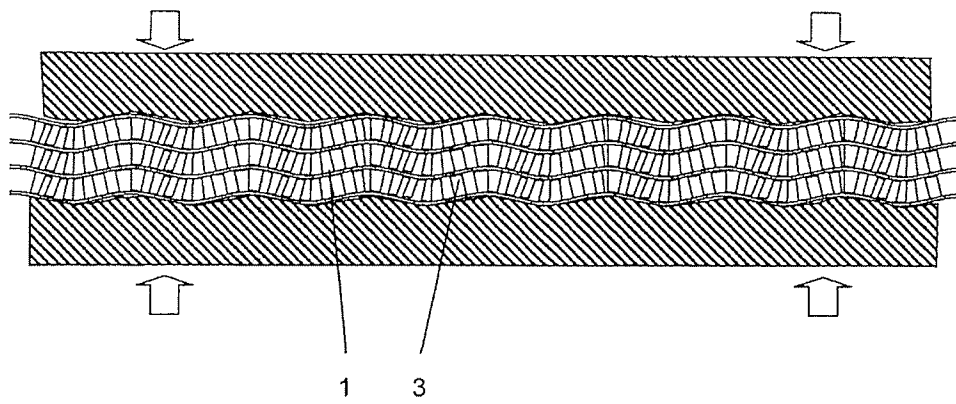
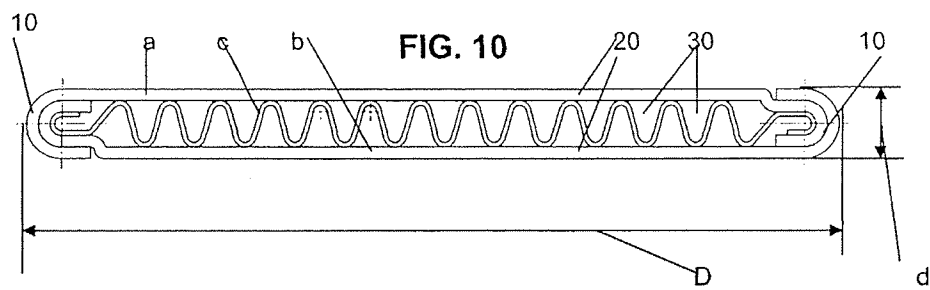
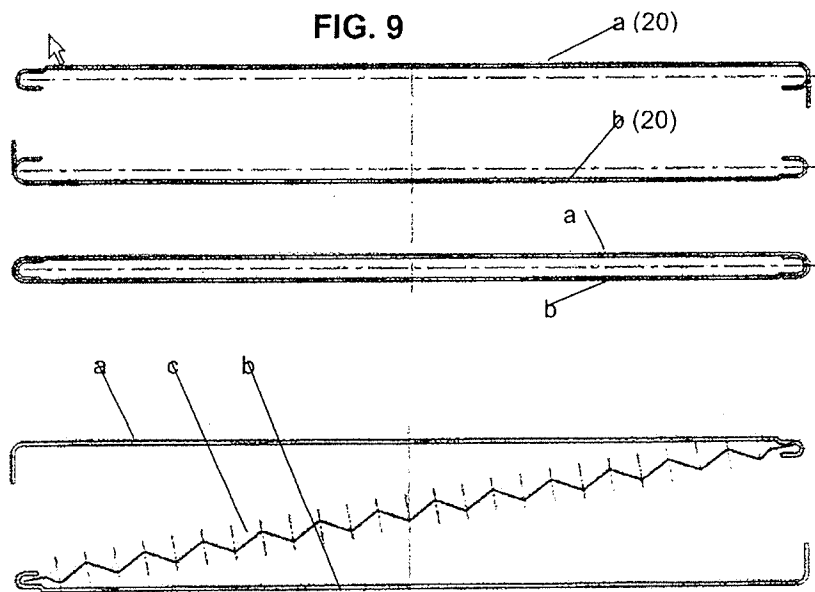
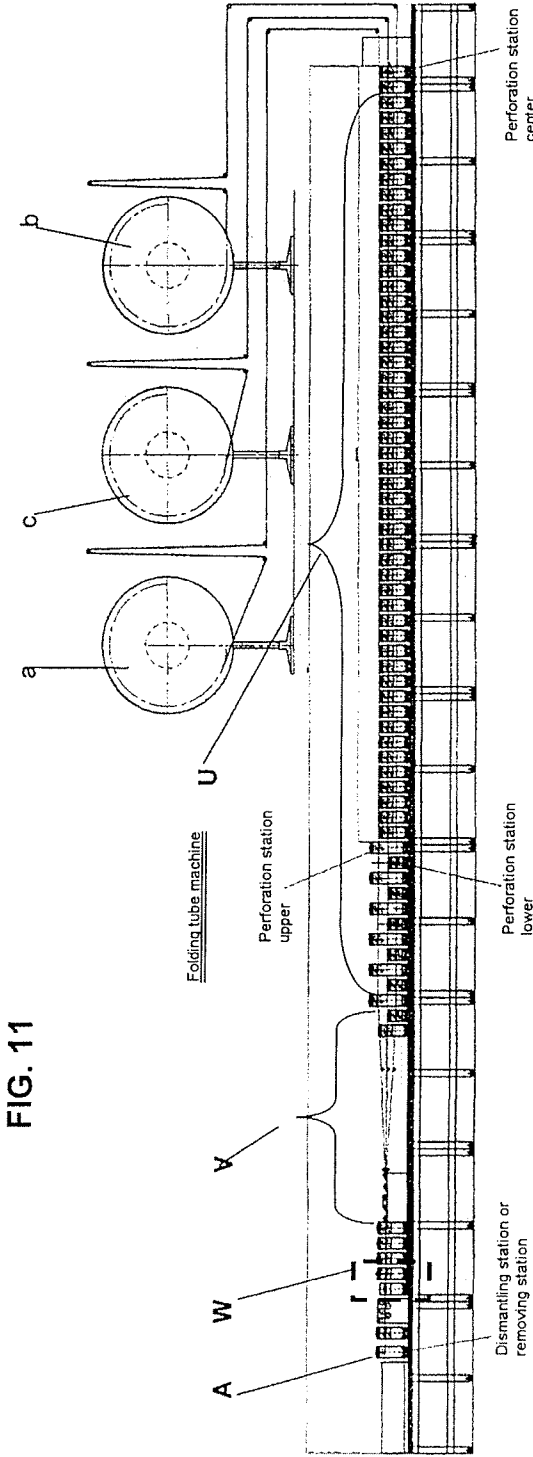


FIG. 8



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A. CLASSIFICATION OF SUBJECT MATTER***F28F 3/00(2006.01)i, F28F 3/02(2006.01)i, F28F 1/02(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)

IPC 8 : B21D 53/02 - 53/08, F28F 1/08, B21C 23/08

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

Korean utility models and applications for utility models since 1975

Japanese utility models and applications for utility models since 1975

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

eKIPASS (KIPO internal) : heat exchanger, flat tube, sheet, ribbon, wave, corrugate, undulate, sinusoidal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004-0069472 A1 (SHIMOYA) April 15, 2004 See abstract, paragraph number 25 to 28 and 33 to 34, and figure 3	1 - 4
Y		5
Y	JP 2002-243378 A (AISIN KEIKINZOKU CO LTD) August 28, 2002 See abstract, paragraph number 9, and figures 1 and 3	5
A		12
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A	US 2005-0161208 A1 (SUCKE ET AL.) July 28, 2005 See abstract and figures	1



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

17 JUNE 2008 (17.06.2008)

Date of mailing of the international search report

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PCT/US2008/050586

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