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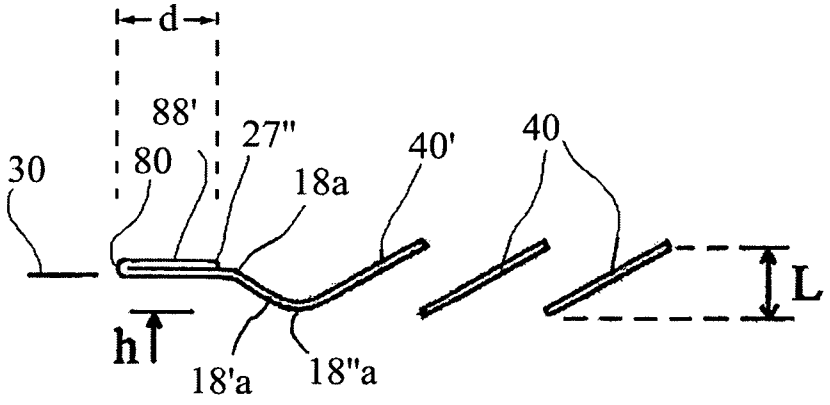
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(54) **Title:** HEAT EXCHANGER FIN



(57) **Abstract:** A serpentine fin for assembly between tubes in a heat exchanger core, and a method of making same from a metal strip. The strip edges preferably have a hem comprising a double thickness of the strip material extending inward from the edge. The metal strip has folds extending across the strip width such that the strip forms a serpentine shape, with the folds being adapted to contact the tubes in the heat exchanger core. Multiple rows of split louvers are disposed between adjacent folds. Each row of split louvers comprises louvers having openings extending in the direction of the strip length and formed in a pair of adjacent, spaced louver banks. Ribs are disposed parallel to the louver openings adjacent the strip edges and in at least one center portion of the strip between the strip edges, and extend across the pair of louver banks. Preferably, the strip has ribs formed both in the center portion and along the edges. After forming the rows of split louvers, pressure is applied to the strip to cause the flat strip to buckle along unformed portions, extending across the strip width between rows of split louvers, thereby forming folds in the strip resulting in the serpentine fin.

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HEAT EXCHANGER FIN

DESCRIPTION

Technical Field

The present invention relates to the manufacture of heat exchangers and the manufacture of fins for heat exchanger cores primarily used in motor vehicles.

Background Art

In the manufacturing of cores for motor vehicle radiators, charge air coolers and other air-cooled heat exchangers, serpentine fins formed from thin gauge metal strip such as copper or aluminum are placed between and in contact with the tubes which carry the fluid to be cooled. The heat exchanger core tubes typically extend between the manifolds, or the inlet and outlet tanks, of the heat exchanger. The fins are the chief heat exchange medium between the coolant and the ambient air. The ability of the fins to transfer heat from the tubes to the air passing over the fins greatly relies on the design of the fins, with some including dimples or protrusions to aid in the heat transfer. To increase the heat transfer rate even further, louvers have been incorporated into the fins. The louvers turbulate the air in a manner which has been found to increase the efficiency of the radiator. The louver configuration may be so-called full louvers, where each louver in the row extends over essentially the entire distance between the tubes, or split louvers, where two side-by-side banks of louvers are employed in the row, so that each of the two louvers extends over less than half of the distance between each tube.

Many heat exchangers employ such serpentine fins, in which a flat metal strip is folded into convolutions to create the multiple fins between spaced tubes. When louvers are incorporated into fins, the structural integrity of the fin is compromised, particularly where serpentine fins are used. A process known as hard-tool forming is typically used in forming the serpentine fin, wherein the louvers are formed with a pair of dies which have a star configuration for forming the convolutions at the same time. The complexity of the dies and machinery for performing the formation of the fins make the process costly. There has been progress made in providing low-cost fin rolls for making ordinary louvered fins by a using them in a process known as

air-forming. In the air-forming process, the rolls only need to have the die formation for the louvers, and the star shape of the roll may be eliminated. As the rolls push out the strip of metal having the cut and formed full louvers, backpressure is applied at different locations to the metal strip to force the metal to buckle, create the convolutions in the strip of metal, and form the finished serpentine configuration in the desired fin per inch density. However, the air-forming process often produces convolutions that are more random in placement with respect to the rows of louvers compared to the use of hard tooling. The use of the air-forming process has been found to distort the full louvers, change the angle of the louvers, and sometimes close the louver opening altogether. Because of the difficulties in forming full louver serpentine fins, it is believed that the air forming process has not been used for split louvers (which offer better heat transfer performance), and that it has been necessary to make split louver serpentine fins solely with a hard tooling process.

Reinforcements to serpentine heat exchanger fins have been described in U.S. Patent Nos. 5,361,829 to Kreutzer et al and 6,918,432 to Ozaki. Such reinforcements have been added to serpentine fins for several reasons. The first, as stated by Kreutzer, is to provide support for flat heat exchanger tubes against bulging due to internal pressure. A second reason, as stated by Ozaki, is to prevent distortion of the fins during washing of the core with water at high pressure. Additionally, serpentine fins are subject to compressive forces during the heat exchanger manufacturing operation of stacking the fins and tubes to make a core assembly. The stacked assembly of fins and tubes is held clamped under pressure during the subsequent soldering or brazing of the core. It has been found that the compressive strength of the serpentine fin is key to obtaining good fin-to-tube contact in the completed core. It has also been found that strengthening the front and rear face of the core by stiffening the leading and trailing edges of the fins provides protection to the core against damage due to handling during manufacturing, shipping and installation, as well as protection in service against damage due to road debris. All of these concerns are aggravated by the desire to use thinner fin materials to save weight and cost.

Disclosure of Invention

Bearing in mind the problems and deficiencies of the prior art, it is therefore an object of the present invention to provide an improved method for manufacturing louvered serpentine fins using an air-forming process.

It is another object of the present invention to provide a method for manufacturing split louvered serpentine fins which is cost-effective, yet produces a quality fin.

A further object of the invention is to provide a method for manufacturing louvered serpentine fins which does not decrease the structural integrity of the fin, and optionally adds increased structural integrity against forces created during the manufacturing process.

It is yet another object of the present invention to provide a method for manufacturing split louvered serpentine fins which results in fins having consistently high efficiency and heat transfer rates.

A further object of the invention is to provide a heat exchanger fin which will have exceptional strength against bulging of the core due to internal pressure, against distortion to the fins due to pressure washing, and against damage in service due to road debris.

Another object of the invention is to provide a heat exchanger fin which has a ribbed hem, for use in a serpentine or plate-type fin.

Yet another object of the invention is to provide an improved method of air forming a serpentine heat exchanger fin using a ribbed hem.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

The above and other objects, which will be apparent to those skilled in the art, are achieved in the present invention which is directed to fins for a heat exchanger core.

The present invention provides a serpentine fin for assembly between tubes in a heat exchanger core comprising a metal strip having a width between opposite strip edges and a length greater that the width. The strip edges have a hem formed thereon comprising a double thickness of the strip material extending a portion of the distance inward from the edge. The metal strip has folds extending across the strip

width such that the strip forms a serpentine shape, with the folds being adapted to contact the tubes in the heat exchanger core. The serpentine fin also includes at least one row of louvers between adjacent folds. The at least one row of louvers comprises louvers having openings extending in the direction of the strip length and formed in adjacent, spaced louver banks extending at least a portion across of the width of the strip. The serpentine fin further includes ribs substantially parallel to the louver openings adjacent the strip edges and in at least one center portion of the strip between the strip edges, the ribs extending across the louver banks.

In the serpentine fin, the hem may extend over a portion of the rib, may extend fully into the rib, or may extend fully into the rib and associated louver. The rib may form a V-shaped channel or a U-shaped channel. Preferably, the louvers are formed at an angle to a plane of the metal strip and the louver angle is between about 26 degrees and about 32 degrees.

Preferably, the metal strip has a thickness and the ribs have a height extending from a plane of the metal strip, and the ratio of the height to the thickness of the metal strip is between about 4 and 5. The ribs are preferably elongated, plastically deformed sections and include at least one angled leg connected to an adjacent louver.

In yet another aspect, the present invention provides a plate-type flat fin for a heat exchanger core having at least one hem along at least a portion of an edge, wherein the hem comprises a double thickness of the strip material extending a portion of the distance inward from the edge; and at least one rib in the hem formed by plastically deforming the metal strip. The fin plate preferably includes louvers.

The present invention is also directed to a method of manufacturing serpentine fins for assembly between tubes in a heat exchanger core. The method includes providing a flat metal strip for making heat exchanger fins, the strip having a width between opposite strip edges and a length greater than the width and forming in the strip, while the strip is substantially flat, multiple rows of split louvers. Each row of louvers has louvers with openings extending in the direction of the strip length and formed in adjacent, spaced louver banks extending at least a portion across of the width of the strip. Each row includes at least one rib formed in the strip substantially parallel to the louver openings and extending across the pair of louver

banks. The metal strip has unformed portions extending across the strip width between rows of split louvers and at least one rib for forming folds across the width of the strip. After forming the rows of split louvers, an initial pressure is applied to the metal strip to cause the substantially flat strip to buckle in the unformed portions and begin to form folds in the strip. At least one row of louvers is between adjacent folds along the length of the strip. Thereafter further pressure is applied to the metal strip to complete formation of the folds of the strip to form the serpentine fin. The distance between the adjacent folds conforms to the desired spacing distance between the heat exchanger core tubes.

The ribs formed in the strip may be along the edges of the strip or the ribs may be in a center portion between the edges. Preferably, the strip will have ribs formed both in the center portion and along the edges.

The ribs are elongated, plastically deformed sections and may include at least one angled leg connected to an adjacent louver. The ribs have a height extending from a plane of the metal strip and the ratio of the height to the thickness of the metal strip is preferably between about 4 and 5.

The louvers have ends adjacent the unformed portions of the metal strip and after applying the further pressure to the metal strip, the distance between the louver ends and the folds at the unformed portions may be substantially equal. The louvers are formed at an angle to a plane of the metal strip and the louver angle is preferably between about 26 degrees and about 32 degrees.

During the formation of the split louvers and the folding of the strip, the strip may be continually moving such that the initial pressure is a backpressure applied by contacting the strip at a first location and such that the further pressure is a further backpressure applied by contacting the strip at a second location downstream of the first location with respect to strip movement.

The present invention further provides an improved method for manufacturing louvered serpentine fins by air forming. The preferred method comprises providing a flat metal strip for making heat exchanger fins, the strip having a width between opposite strip edges and a length greater than the width. Each of the opposite strip edges is a hemmed edge comprising a double thickness of the flat metal strip and extending a portion of the distance inward from the edges to

form a hem. The method includes forming in the strip, while the strip is substantially flat, multiple rows of louvers. Each row of louvers comprises louvers having openings extending in the direction of the strip length and formed in adjacent, spaced louver banks extending at least a portion across of the width of the strip. At least one rib is formed in the strip, which rib is substantially parallel to the louver openings and extends across the louver banks. The metal strip has unformed portions extending across the strip width between rows of strip louvers and ribs for forming folds across the width of the strip. After forming the rows of louvers, the method includes applying an initial pressure to the metal strip to cause the substantially flat strip to buckle in the unformed portions and begin to form folds in the strip, with at least one row of louvers between adjacent folds along the length of the strip, and thereafter applying further pressure to the metal strip to complete formation of the folds of the strip to form the serpentine fin. The distance between the adjacent folds conforms to the desired spacing distance between the heat exchanger core tubes.

The method preferably includes folding each of the opposite strip edges to form the hemmed edge, such that the hem extends over a portion of the rib, the hem extends fully into the rib, or the hem extends fully into the rib and associated louver.

In the air forming method the strip is continually moving. The initial pressure is a backpressure applied by contacting the strip at a first location and the further pressure is a further backpressure applied by contacting the strip at a second location downstream of the first location with respect to strip movement.

The rib may be formed adjacent the strip edges and/or in a center portion of the strip between the strip edges. The rib is preferably an elongated, plastically deformed section and may include at least one angled leg connected to an adjacent louver The louvers preferably have ends adjacent the unformed portions of the metal strip and wherein after applying the further pressure to the metal strip, the distance between the louver ends and the folds at the unformed portions is substantially equal.

In another aspect the invention is directed to a serpentine fin for assembly between tubes in a heat exchanger core. The serpentine fin comprises a metal strip having a width between opposite strip edges and a length greater than the width and having multiple rows of split louvers. Each row of split louvers comprises louvers having openings extending in the direction of the strip length and formed in a pair of

adjacent, spaced louver banks extending at least a portion across of the width of the strip. The strip includes ribs formed in the strip substantially parallel to the louver openings adjacent the strip edges and in a center portion of the strip between the strip edges and extending across the pair of louver banks. The metal strip has unformed portions extending across the strip width between rows of strip louvers and ribs, wherein the strip has folds along the unformed portions extending across the strip width such that the strip forms a serpentine shape with at least one row of split louvers between adjacent folds. The folds are adapted to contact the tubes in the heat exchanger core.

Brief Description of the Drawings

The features of the invention believed to be novel and the elements characteristic of the invention are set forth with particularity in the appended claims. The figures are for illustration purposes only and are not drawn to scale. The invention itself, however, both as to organization and method of operation, may best be understood by reference to the detailed description which follows taken in conjunction with the accompanying drawings in which:

Fig. 1 is a top plan view of a metal strip having split louvers formed therein in accordance with the present invention.

Fig. 2 is a cross sectional view of the split louvers of Fig. 1 along line 2-2.

Fig. 3 is a close up view of the portion of Fig. 2 in the vicinity of the end rib in the split louvers, wherein the strip edge has a single thickness.

Fig. 4 is a close up view of the portion of Fig. 2 in the vicinity of the center rib in the split louvers.

Fig. 5 is a close up view of the portion of Fig. 2 in the vicinity of the end rib in the split louvers, wherein the strip edge has a double thickness, hemmed edge extending toward the end rib.

Fig. 6 is an alternate embodiment of Fig. 5, wherein the double thickness of the hemmed edge extends fully over the end rib.

Fig. 7 is another embodiment of Fig. 5, wherein the double thickness of the hemmed edge extends fully into the end rib and the associated louver.

Fig. 8 is yet another embodiment of Fig. 5, wherein the rib is a sharp peak with the hemmed edge extending thereunder.

Fig. 9 is a further embodiment of Fig. 5, wherein the rib is a downward facing curved peak with the hemmed edge extending thereover.

Fig. 10 is another embodiment of Fig. 5, wherein the rib is an upward facing curved peak with the hemmed edge extending thereunder.

Fig. 11 is a cross-sectional elevational view, perpendicular to the length of the metal strip, showing the progressive formation of the hemmed edges.

Figs. 12-15 are side elevational views of an air forming machine showing the forming of the louvers and ribs by fin rolls, and the progression of the forming of the convolutions of the serpentine strip.

Fig. 16 is a front view of a portion of a heat exchanger core face showing a serpentine split louver fin of the present invention between heat exchanger core tubes.

Fig. 17 is an end view of a heat exchanger core showing a serpentine split louver fin of the present invention between heat exchanger core tubes.

Fig. 18 is a perspective view of a portion of a heat exchanger core showing serpentine split louver fins of the present invention sandwiched between heat exchanger core tubes.

Modes for Carrying Out the Invention

In describing the preferred embodiment of the present invention, reference will be made herein to Figs. 1-18 of the drawings in which like numerals refer to like features of the invention.

Figs. 1-4 depict a split louver fin configuration formed in a flat metal strip in accordance with the present invention, prior to forming the serpentine convolutions. A length of metal strip 12 of aluminum or preferably copper has split louvers 40 extending in rows 25 across the width of the strip, ribs 18a and 18b formed adjacent the louvers within the rows, and unformed portions 22 extending across the strip width between rows of the louvers. The louvers are formed by cutting the strip and twisting and plastically deforming the cut portions. The opposite ends of each of the louvers maintain connection with the remaining metal strip by a twist portion. Each

row 25 of split louvers is made up of a pair of banks 25a, 25b of individual louvers 40, which are separated from each other by unformed portion 24 extending in the direction of the strip width. The adjacent, spaced louver banks 25a, 25b extend across at least a portion of the width of the strip 12, and preferably extend across substantially all of the strip width. The louvers 40, the openings between the louvers, and ribs 18a, 18b extend in the direction of the strip length 21.

Ribs 18a, 18b are plastically deformed in the strip substantially parallel to the louver openings in the direction of the strip length and extend substantially completely across the pair of louver banks 25a, 25b, including across the unformed strip portion 24 between the louver banks. End ribs 18a are located near the strip edges 27 and center ribs 18b are located in center portions of the strip between the strip edges. Ribs 18a, 18b extend across the pair of louver banks, but not beyond the ends of the louvers into the unformed sections 22 separating the rows of louvers. End ribs 18a shown in the detailed view of Fig. 3 have plastically deformed portions and include one angled leg 18'a extending at an angle downward from the plane 30 of the undeformed metal strip and a bent portion 18"a that connects to the adjacent louver 40. The end ribs are ultimately positioned, after assembly of the fin in the core, near the upstream and downstream ends of the fin relative to the direction of cooling airflow. Center ribs 18b shown in the detailed view of Fig. 4 also have plastically deformed portions with angled legs 18'b extending at an angle downward from an undeformed metal strip portion in plane 30 and bent portions 18"b that connect to the adjacent split louvers 40. The number and spacing of center ribs 18b among the louvers in each row may be determined according to the strength requirements of the strip during air forming, as will be described in more detail below. As shown in Figs. 3 and 4, each split louver 40 has a total height L and is angled at an angle α from the neutral plane 30 of the undeformed metal strip 12. In one preferred embodiment, the strip and louvers have a thickness of about 0.0022 in. (0.056 mm), and the louvers have angle α of about 30° and height L of about 0.023 in. (0.58 mm). The ribs have a height distance h in one direction from the neutral plane of about 0.0104 in. (0.26 mm). The ratio of h/s is about 4.7, and signifies that the height of the rib is about 4.7 times the thickness of the fin material.

The metal strip may be made with a single thickness edge as shown in Fig. 3, where edge 27 is of the same thickness as the remainder of the strip material. However, in the preferred embodiment, to add structural integrity to the fin, the metal strip may include a hem along each of the opposite edges along which the end ribs are formed. The hem comprises a double thickness of the metal strip material and extends at least a portion inward from the edge. The distance to which the hem extends inward may vary as shown in the embodiments of Figs. 5-7. The hem 88 is formed by folding a portion of the original cut metal strip edge 27 (Figs. 1 and 3), thereby forming a double thickness of the metal strip, and is described further below. The result is that the original cut metal edge is now inward 27" by distance *d* of the new hem edge 80 along which the metal strip is folded and which now forms the leading and trailing edges of the final heat exchanger product. This distance d of the fold may vary, as described below.

Similar to the embodiment shown in Fig. 3, the invention having the hemmed edges also includes end ribs 18a having a plastically deformed angled leg 18'a and a bent portion 18"a. The embodiment shown in Fig. 5 has the hem extending only a portion of the distance from the hem edge 80 to the end rib 18a, wherein no portion of the end rib 18a or the associated louver 40' is in the hemmed area. Preferably, as shown in Fig. 6, the hem 88' extends from the hem edge 80 to a point partially or fully encompassing the end rib 18a, and more preferably, the hem 88" extends fully into the end rib and partially or fully into the associated louver 40'. In other words, the end rib adjacent the edges of the metal strip may comprise a double thickness of the metal strip in part of the rib, in the entire rib or the entire rib along with a portion or the entirety of the associated louver. The associated louver 40' is defined as the louver formed with and is attached to the adjacent end rib 18a.

By folding over the leading and trailing edges of the serpentine fin, the formed hem of double thickness provides structural integrity to the fin, both from forces encountered during use of the heat exchanger, and from compression forces incurred during the manufacturing of the heat exchanger. This structural reinforcement is improved further when the end rib 18a is formed in the hemmed area, either partially embedded in the hem or fully embedded in the hem. The hem may extend far enough inward to also incorporate the associated louver either

partially or fully, increasing the resistance to external forces even further. This embodiment results in exceptional rigidity and provides superior resistance to fin and core damage.

Figs. 8-10 shows examples of a rib 82 embedded in the hemmed area wherein the rib has various cross-sectional patterns. Fig. 8 shows a rib having cross-sectional pattern with a sharp peak formed by angled legs 82', 82" with the tip of the peak positioned upward in the same direction as the open edge 85 of the associated louver with respect to the neutral plane 30 of the unformed metal strip. Fig. 9 shows a rib having a curved peak 86 with the crest of the peak 86' downward facing, opposite the direction of the open edge of the associated louver and Fig. 10 has a curved peak 86 with the crest of the peak facing upward in the same direction as the open edge of the associated louver. The variations in the cross sectional patterns of the rib, the distance to which the hem extends to or into the rib and associated louver, and the direction the peak of the rib faces may be further combined in a multitude of embodiments not specifically described.

The ribbing of the hemmed area may also be incorporated into the design and manufacturing of plate-type flat fins. In this aspect of the invention, the plate-type fin is hemmed along at least one of the fin edges and includes at least one rib formed in the hemmed area. This embodiment is not formed into a serpentine fin, but remains essentially flat, and gives the plate-type fin resistance to damage during handling of the fins during manufacture and transport and against stresses during use of the heat exchanger core.

The fin of the present invention employing a ribbed hem may be made by conventional hard tooling or by air forming.

The process of air forming the serpentine split louver fins of the present invention is shown in Figs. 11-15, and begins by providing a coil of unformed metal strip for continuous feeding through a modified prior art air forming machine 10. If the hemmed edges are to be employed, folding of the unformed metal strip edges to produce hemmed edges may be completed before the metal strip enters the air forming machine or as a step during the process of forming the heat exchanger fin after the metal strip is fed into the air forming machine. Fig. 11 shows the partial

folding of cut strip edges 27 to a first position 27' and subsequently to the final folded position 27" to form hem 88.

As shown in Fig. 12, the air forming machine 10 comprises a front roller 50 which guides the metal strip through a pair of opposing wiping pads 52, one on each side of the metal strip, for cleaning any contamination thereon. A pair of counter rotating fin rolls 60, 62 having a cylindrical shape are positioned downstream from the wiping pads with respect to the metal strip. If formation of the hem is to be made in the air forming machine, the folding operation may be made immediately after the wiping stage and prior to contact with the fin rolls. Fin rolls 60, 62 are sufficiently close to one another to exert a compression force on the surface of the moving metal strip in a direction normal to the strip plane, as well as move the strip continuously in direction 21. Unlike prior air forming machines, the surfaces of each of the fin rolls 60, 62 have a plurality of meshing cutter blades and tool patterns 44 which cut and form the split louvers 40 and ribs 18a, 18b in the metal strip, to the configuration shown in Figs. 1-4.

As the fin rolls 60, 62 push the metal strip downstream 21, the formed metal strip passes between a backing plate 68 and a first base portion 48a, which contact the strip to maintain it in a substantially flat position. The metal strip 12 continues to move downstream from the backing plate and into contact with a pair of counter rotating folding shafts 70, 72 respectively positioned above and below the strip plane. Each folding shaft 70, 72 has a plurality of arms extending outward from the axis of rotation, and the ends of the arms are parallel to the strip width. As shown in Fig. 12, the metal strip contacts arms of the rotating lower folding shaft 72 and upper folding shaft, which arms provide an initial backpressure in a direction opposite to the motion of the strip in direction 21. In particular, the metal strip contacts one of the lower folding shaft 72 arms forcing an unformed portion 22 into a radius formed between shaft arms, creating the initial backpressure on the metal strip between the backing plate 68 and the lower folding shaft 72. As the backpressure is applied, strip 12 begins to buckle along a first unformed portion 22 between backing plate 68 and lower folding shaft 72. The unformed portions 22 of the metal strip have the least amount of structural integrity against forces which tend to make the metal strip bend across its width, while the split louvers and the ribs inhibit buckling and folding in

the louver rows. The term air forming refers to the fact that the folds are made in a controlled fashion in air without the necessity to use male and female tool sections conforming to the desired degree of folding.

Fig. 13 shows the result of the initial backpressure causing the metal strip to buckle along the unformed portions 22'a creating a fold in one direction, and to buckle along the unformed portion 22'b creating a fold in the opposite direction. As the metal strip moves from backing plate 68 to folding shafts 70, 72, it continues to buckle, and additional folds 22'a, 22'b created along the adjacent unformed portions 22 to create the folds or convolutions in the strip between each row 25 of split louvers. The fold angles continue to increase as the strip approaches and passes between the folding shafts, as shown in Figs. 14 and 15, which show the progression of the strip folding.

A further backpressure is applied to the convoluted strip by a gathering station downstream of the folding shafts, again in a direction opposite to the strip movement direction 21. As shown in Figs. 13, 14, and 15, this gathering station, has fingers 96, preferably in the form of a metal brush, mounted on an adjustable lever 98 which sequentially contact the upper folds 22' of the convoluted strip as it passes in direction 21. The force of fingers 96 urges the convoluted strip against a second base portion 48b, and may be adjusted to apply sufficient backpressure to create the desired density of strip convolutions, i.e., the number of straight portions containing split louver fins 25 (between folds) in a distance D of formed serpentine fin strip 12'. This fin strip density is typically described as number of fins per inch. Increased backpressure at the gathering station produces a higher fin density, while lower backpressure at the gathering station results in a lower fin density. The air forming process continues until the final fold angle is obtained at folded unformed portions 22' to form the desired number of folds into a length of fin strip 12'. The fin strip 12' is subsequently cut to create the desired number of fins corresponding to the length of the tubes in the heat exchanger core.

Figs. 16, 17 and 18 show the completed serpentine fin strips 12' integrated with tubes 30 to form heat exchanger core 50. As shown in Fig. 18, incoming air flowing in direction 35 enters core 50 at leading fin edge 31 and exits at trailing fin

edge 33. The serpentine fin strips 12' are stacked in an alternating pattern with the tubes, and then compressed and brazed to form the completed core.

One particular advantage of the use of ribs with the split louver serpentine fin made by air forming is shown in Fig. 16 with respect to the location of the ends of the individual louvers 40 from adjacent tubes 30. It is desirable to ensure that there is sufficient distance x_1 and x_2 between the louver ends and the tubes, so that the fold is confined to the unformed area between louver rows, and the ends of the louvers are not distorted, closed or crushed, or the louver angle changed, by the folding process. The present invention of air forming a split louver serpentine fin has been shown to provide such distance to avoid damage to the louvers, and more importantly, provide a consistent distance x_1, x_2 between the louver ends and the tubes, preferably where x_1 is substantially equal to x_2, to permit the as-built heat exchanger to come closer to the theoretical performance of the design. The ribs formed within the split louver give the louver banks more integrity in the structure during the air forming of the convolutions as well as in the production of the radiator core when the tubes and fin strips are stacked and brazed.

A serpentine fin which has a hemmed leading edge where the air enters the heat exchanger, and preferably hemmed leading and trailing edges, will provide for a heat exchanger which has greater structural integrity during the manufacturing process and during use. During the brazing process of attaching the fins to the tubes during manufacturing, the hemmed edges, and particularly the hemmed edges having ribs therein, allow for greater compression of the stacked fins and tubes without damaging or distorting the fins. During installation of the heat exchanger, the hemmed edges give the fins protection from distortion or damage from the installer and, in use of the final product, the hemmed edges protect the fins from damage due to road debris, power washing, and repair. The hemmed edges also aid in reinforcing the tubes during pressure cycling of the heat exchanger where the tubes have a tendency to expand or bulge from internal pressure of the heat exchanger.

Thus, the present invention provides an improved method for manufacturing split louvered serpentine fins using an air-forming process, which is cost-effective, yet produces a quality fin having consistently high efficiency and heat transfer rates. The invention also provides a serpentine fin with a hemmed leading edge and

preferably, hemmed leading and trailing edges, including split louvers and reinforcement ribs which add increased structural integrity against forces created during the manufacturing process. Preferably at least one of the ribs is formed partially or fully within the hemmed area to provide exceptional rigidity to the leading and trailing edges of the heat exchanger fin, whether it is serpentine or plate-type. The resulting increased rigidity provides superior resistance to fin and core damage resulting from handling, shipping and installation, and from pressure washing and road debris in use in the vehicle. This increased rigidity permits the use of thinner fin materials while preserving the aforementioned fin resistance to core damage. The above applies to full-louver serpentine fins as well.

While the present invention has been particularly described, in conjunction with a specific preferred embodiment, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art in light of the foregoing description. It is therefore contemplated that the appended claims will embrace any such alternatives, modifications and variations as falling within the true scope and spirit of the present invention.

Thus, having described the invention, what is claimed is:

Claims

1. A serpentine fin for assembly between tubes in a heat exchanger core comprising:

a metal strip having a width between opposite strip edges and a length greater that the width, the strip edges having a hem formed thereon comprising a double thickness of the strip material extending a portion of the distance inward from the edge, the metal strip having folds extending across the strip width such that the strip forms a serpentine shape, the folds being adapted to contact the tubes in the heat exchanger core,

at least one row of louvers between adjacent folds, the at least one row of louvers comprising louvers having openings extending in the direction of the strip length and formed in adjacent, spaced louver banks extending at least a portion across of the width of the strip; and

ribs substantially parallel to the louver openings adjacent the strip edges and in at least one center portion of the strip between the strip edges, the ribs extending across the louver banks.

2. The fin of claim 1 wherein the hem extends over a portion of the rib.

3. The fin of claim 1 wherein the hem extends fully into the rib.

4. The fin of claim 1 wherein the hem extends fully into the rib and associated louver.

5. The fin of claim 1 wherein the rib forms a V-shaped channel.

6. The fin of claim 1 wherein the rib forms a U-shaped channel.

7. The fin of claim 1 wherein the louvers are formed at an angle to a plane of the metal strip and the louver angle is between about 26 degrees and about 32 degrees.

8. The fin of claim 1 wherein the metal strip has a thickness and the ribs have a height extending from a plane of the metal strip, and wherein the ratio of the height to the thickness of the metal strip is between about 4 and 5.

9. The fin of claim 1 wherein the ribs are elongated, plastically deformed sections and include at least one angled leg connected to an adjacent louver.

10. A plate-type flat fin for a heat exchanger core having:

at least one hem along at least a portion of an edge of the fin wherein the hem comprises a double thickness of the strip material extending a portion of the distance inward from the edge; and

at least one rib or portion thereof in the hem formed by plastically deforming the metal strip.

11. The fin of claim 10 wherein the fin plate includes louvers.

12. A method of manufacturing serpentine fins for assembly between tubes in a heat exchanger core comprising:

providing a flat metal strip for making heat exchanger fins, the strip having a width between opposite strip edges and a length greater than the width;

forming in the strip, while the strip is substantially flat, multiple rows of split louvers, each row of louvers comprising louvers having openings extending in the direction of the strip length and formed in adjacent, spaced louver banks extending at least a portion across of the width of the strip, and including at least one rib formed in the strip substantially parallel to the louver openings and extending across the pair of louver banks, the metal strip having unformed portions extending across the strip width between rows of strip louvers and at least one rib for forming folds across the width of the strip;

after forming the rows of split louvers, applying an initial pressure to the metal strip to cause the substantially flat strip to buckle in the unformed portions

and begin to form folds in the strip, with at least one row of louvers between adjacent folds along the length of the strip; and

thereafter applying further pressure to the metal strip to complete formation of the folds of the strip to form the serpentine fin, the distance between the adjacent folds conforming to the desired spacing distance between the heat exchanger core tubes.

13. The method of claim 12 wherein the strip is continually moving and wherein the initial pressure is a backpressure applied by contacting the strip at a first location and wherein the further pressure is a further backpressure applied by contacting the strip at a second location downstream of the first location with respect to strip movement.

14. The method of claim 12 including forming ribs adjacent the strip edges.

15. The method of claim 12 including forming the at least one rib in a center portion of the strip between the strip edges.

16. The method of claim 12 including forming ribs adjacent the strip edges and in a center portion of the strip between the strip edges.

17. The method of claim 12 wherein the louvers have ends adjacent the unformed portions of the metal strip and wherein after applying the further pressure to the metal strip, the distance between the louver ends and the folds at the unformed portions is substantially equal.

18. The method of claim 12 wherein the at least one rib comprises an elongated, plastically deformed section and include at least one angled leg connected to an adjacent louver.

19. The method of claim 12 wherein the metal strip has a thickness and the at least one rib has a height extending from a plane of the metal strip, and wherein the ratio of the height to the thickness of the metal strip is between about 4 and 5.

20. The method of claim 12 wherein the louvers are formed at an angle to a plane of the metal strip and the louver angle is between about 26 degrees and about 32 degrees.

21. The method of claim 12 wherein, in the flat metal strip, each of the opposite strip edges is a hemmed edge comprising a double thickness of the flat metal strip extending a portion of the distance inward from the edges to form a hem.

22. The method of claim 21 further including folding each of the opposite strip edges to form the hemmed edge.

23. The method of claim 21 wherein the hem extends over a portion of the rib.

24. The method of claim 21 wherein the hem extends fully into the rib.

25. The method of claim 21 wherein the hem extends fully into the rib and associated louver.

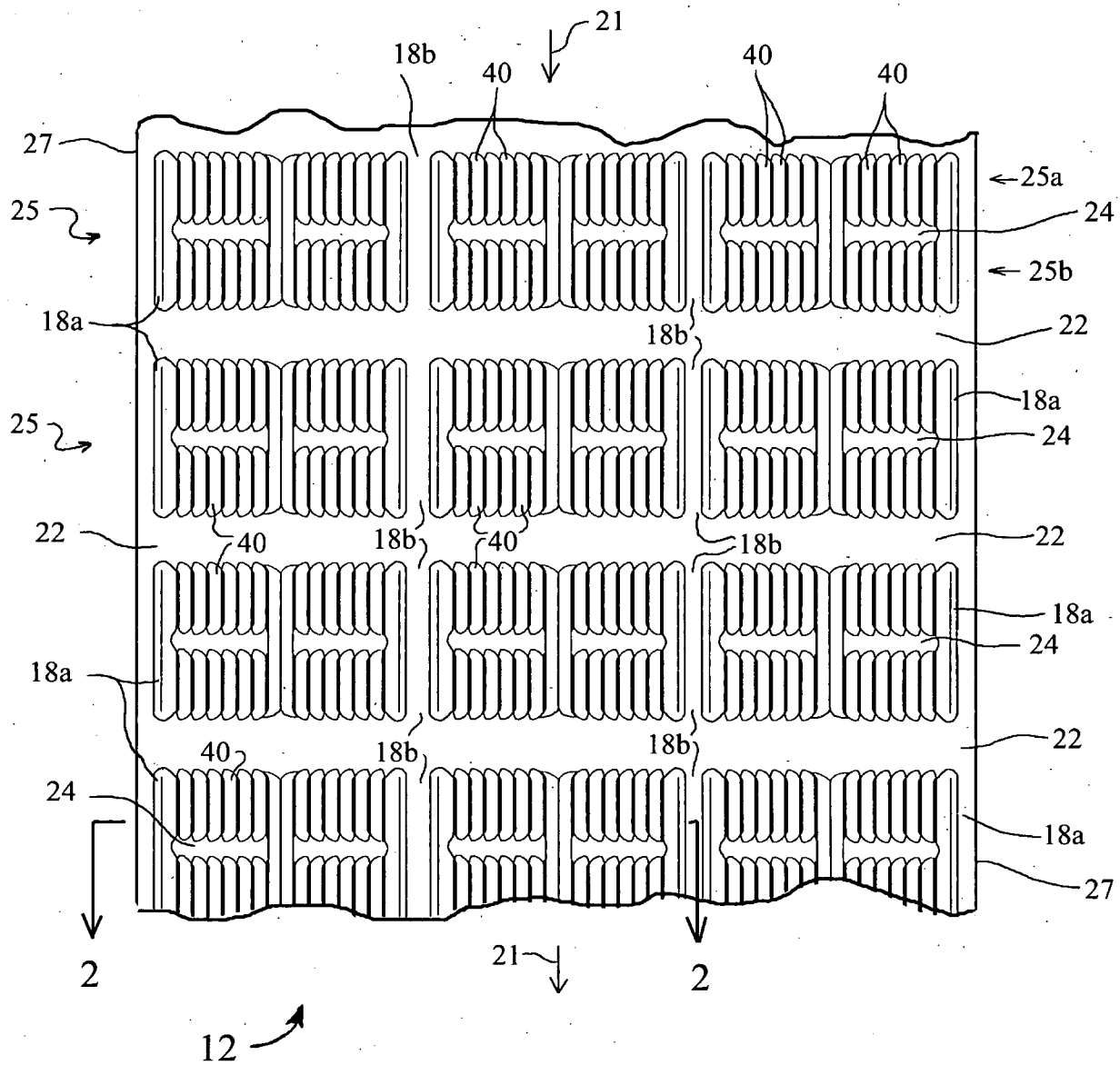

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18b
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Fig. 1

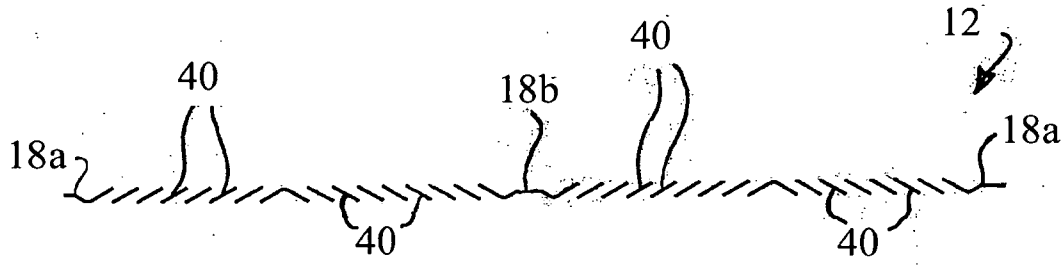


Fig. 2

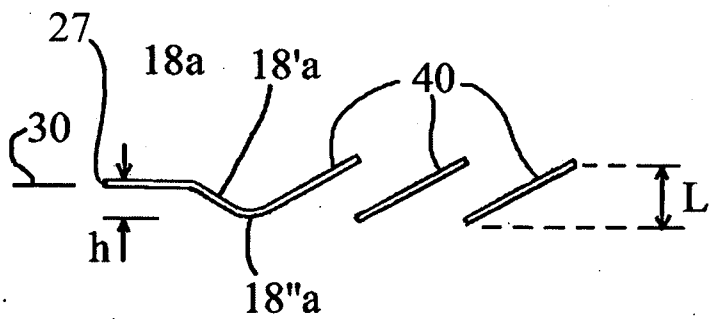


Fig. 3

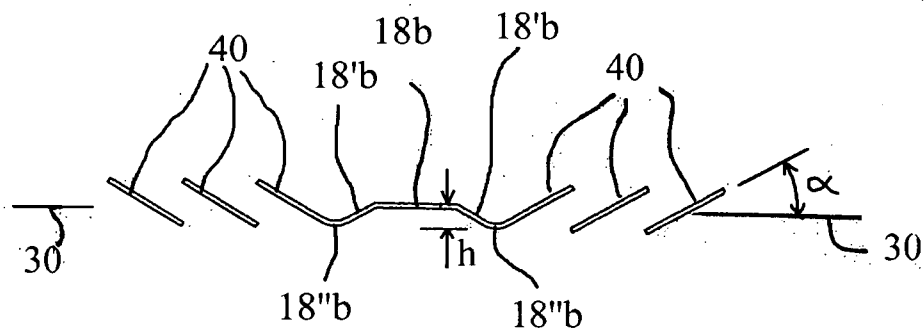


Fig. 4

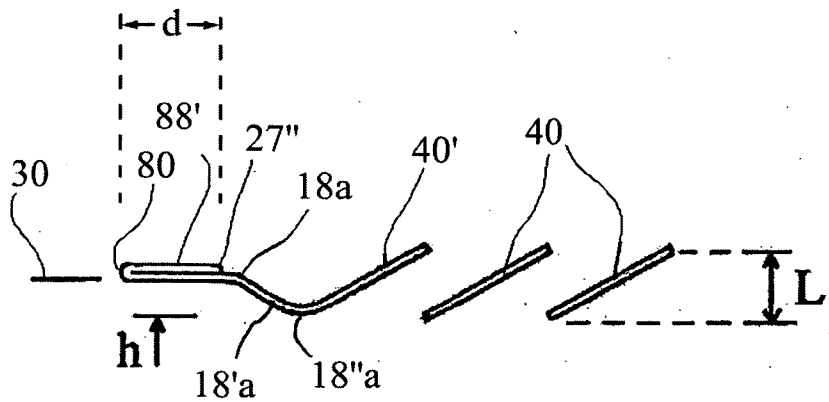


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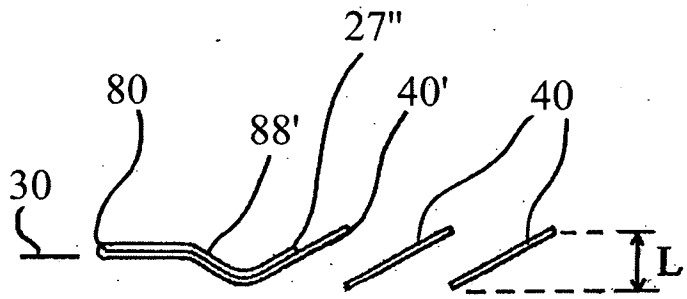


Fig. 6

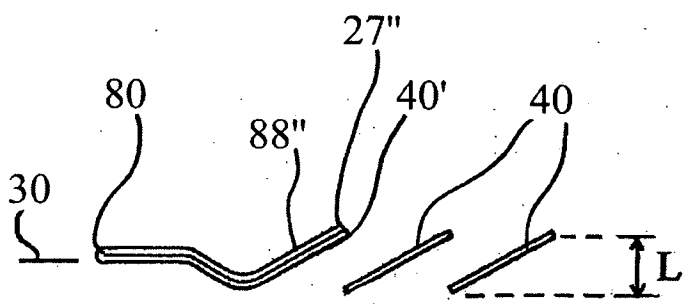


Fig. 7

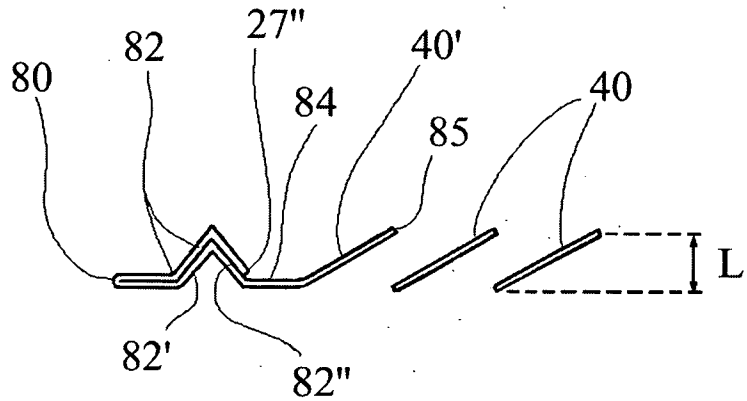


Fig. 8

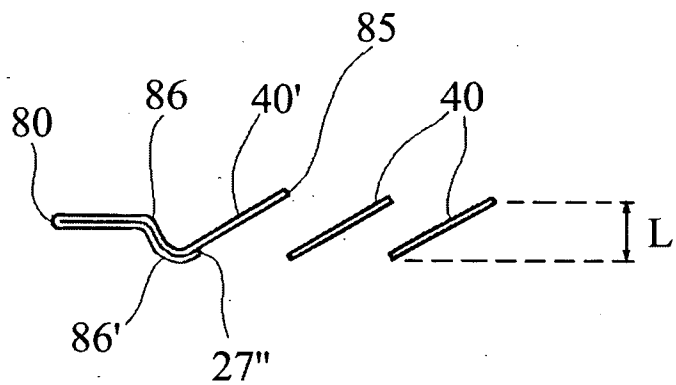


Fig. 9

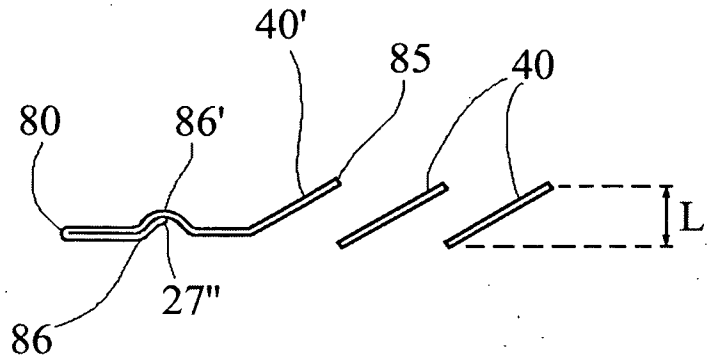


Fig. 10

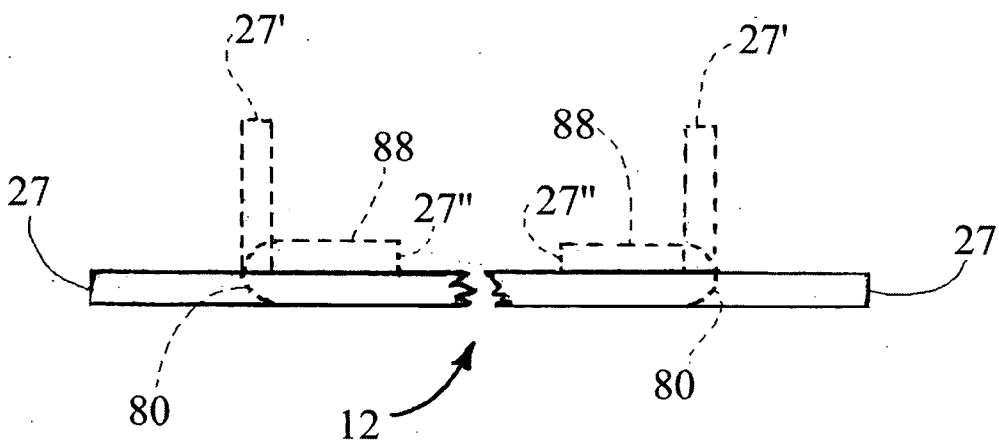


Fig. 11

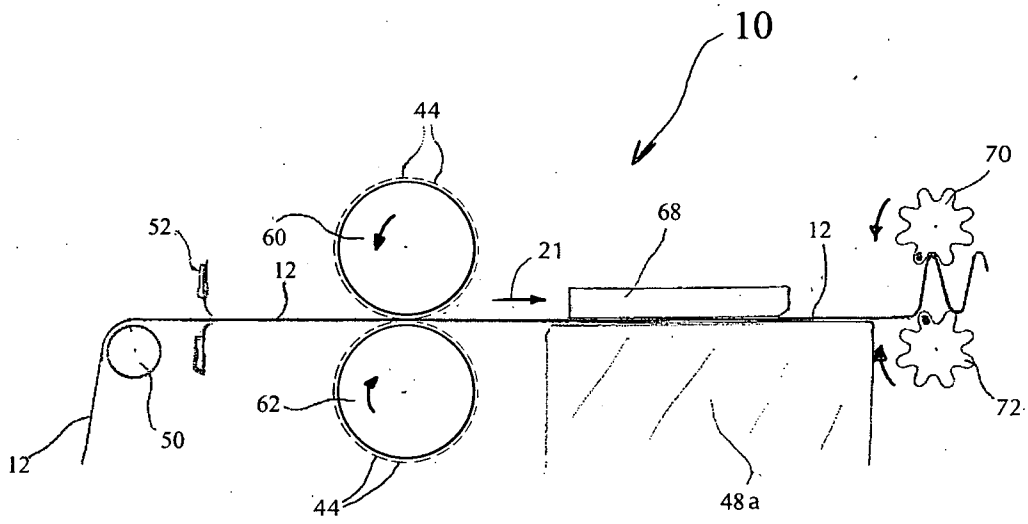

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Fig. 12

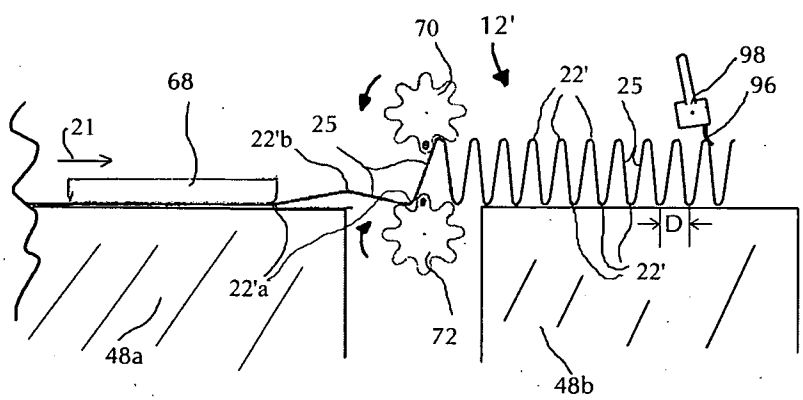

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22'
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96
21
22'b
25
D
22'
22'a
72
48a
48b

Fig. 13

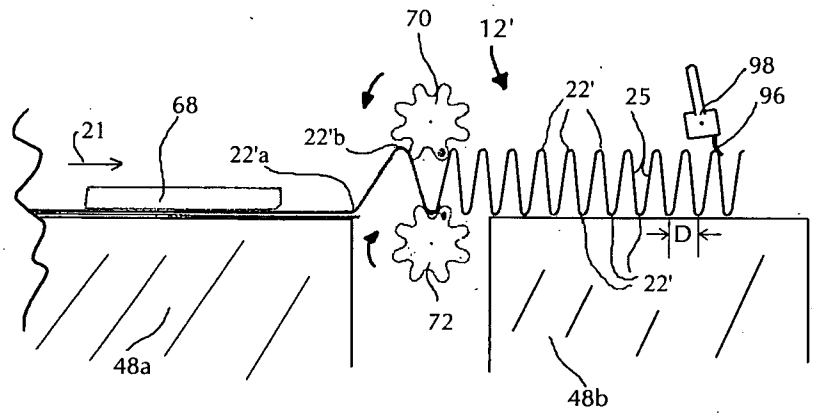

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22'
72
48a
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Fig. 14

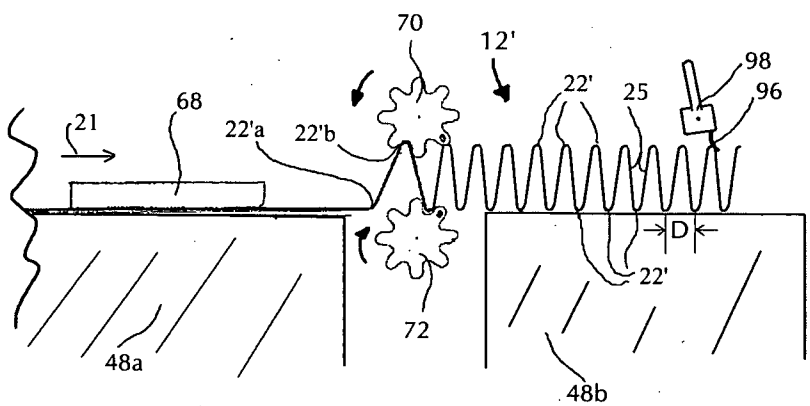

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22'
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22'a
22'b
D
22'
72
48a
48b

Fig. 15

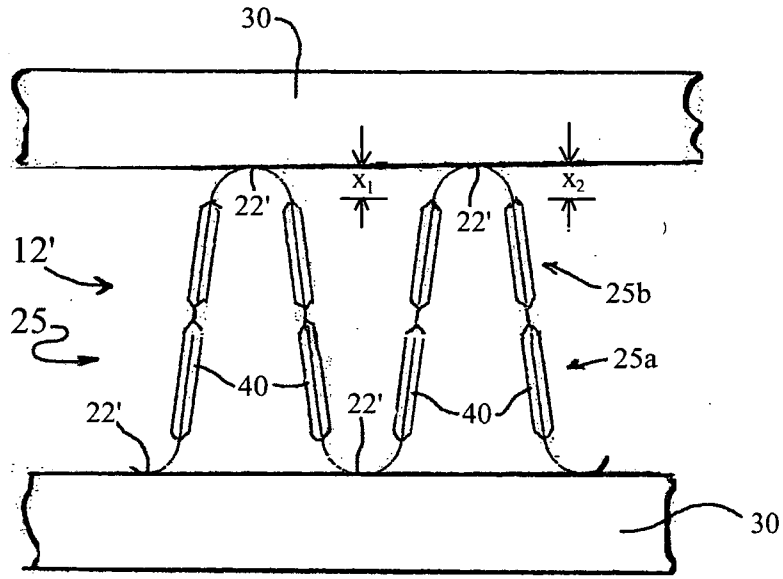

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x_1
x_2
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22'
22'
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Fig. 16

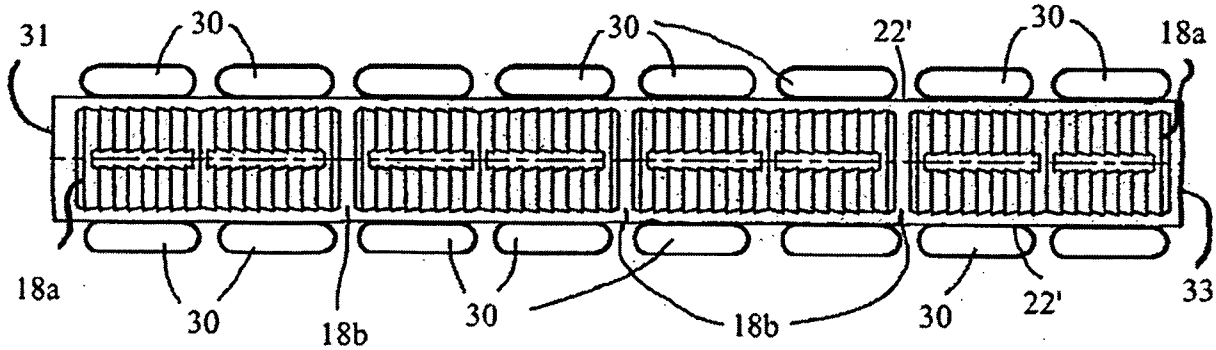

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18b
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22'
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Fig. 17

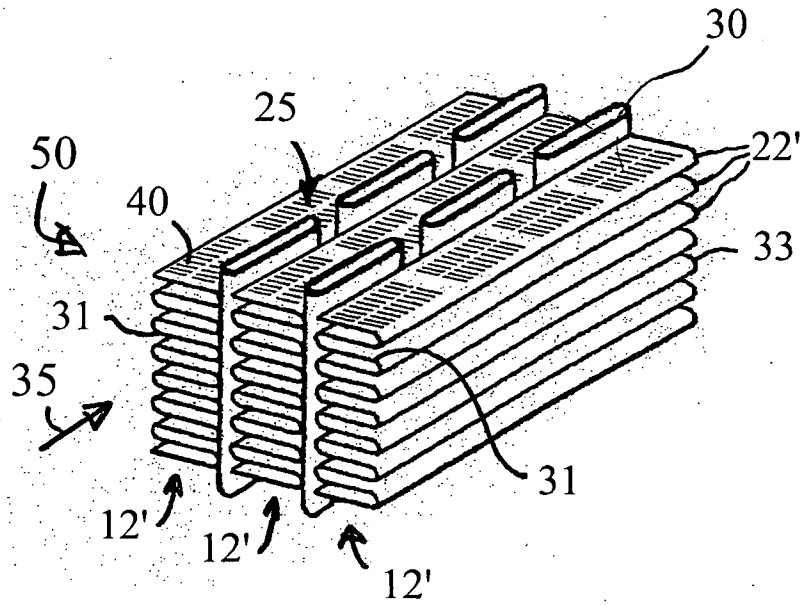


Fig. 18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2007/025559

A. CLASSIFICATION OF SUBJECT MATTER

F28F 3/02(2006.01)i, F28F 1/32(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)

IPC 8 : F28F 1/32, 1/30

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) : fin, hem*, flange, brim*, strut

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2002-147982 A (TOYO RADIATOR CO. LTD) May 22, 2002 See paragraph number <4> and <7> and figures	1 - 4, 10, 11
Y		5, 6, 7, 9, 12 - 18, 20 - 25
Y	JP 62-018583 U (JAPAN RADIATOR CO. LTD) February 4, 1987 See whole document	5, 6, 9, 18
A		8, 19
Y	JP 2000-154989 A (DAIKIN IND LTD) June 6, 2000 See paragraph number <43> to <46> and figure 10	7, 20
Y	JP 06-180192 A (NIPPONDENSO CO. LTD) June 28, 1994 See paragraph number <10> to <14> and figure 4	12 - 18, 20 - 25

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 MARCH 2008 (20.03.2008)	**21 MARCH 2008 (21.03.2008)**

Name and mailing address of the ISA/KR

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Facsimile No. 82-42-472-7140

Authorized officer

LEE, Byung Jae

Telephone No. 82-42-481-8560

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2007/025559

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2002-147982 A	22.05. 2002	None	
JP 62-018583 U	04.02. 1987	None	
JP 2000-154989 A	06.06. 2000	None	
JP 06-180192 A	28.06. 1994	None	