(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 795 849 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 158(3) EPC

(43) Date of publication:
**13.06.2007 Bulletin 2007/24**

(21) Application number: **05785742.7**

(22) Date of filing: **22.09.2005**

(51) Int Cl.:
***F28F 1/30*** *(2006.01)* ***B21D 13/04*** *(2006.01)*
***B21D 28/10*** *(2006.01)* ***B21D 28/12*** *(2006.01)*
***B21D 53/08*** *(2006.01)* ***B23P 13/00*** *(2006.01)*

(86) International application number:
**PCT/JP2005/017455**

(87) International publication number:
**WO 2006/033382 (30.03.2006 Gazette 2006/13)**

(84) Designated Contracting States:
**DE FR GB**

(30) Priority: **22.09.2004 JP 2004274877**
**09.11.2004 JP 2004325485**

(71) Applicant: **Calsonic Kansei Corporation**
**Tokyo 164-8602 (JP)**

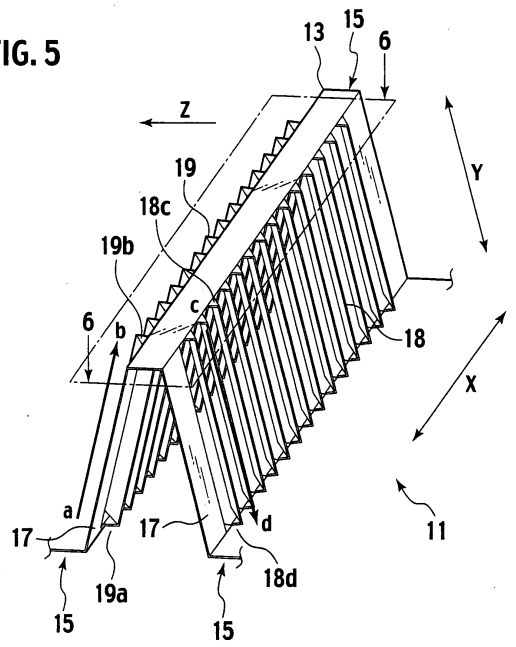
(72) Inventors:
- **YAEZAWA, Hirokazu, c/o Calsonic Kansei Corporation**
**Tokyo 164-8602 (JP)**
- **TOCHIGI, Kenji, c/o Calsonic Kansei Corporation**
**Tokyo 164-8602 (JP)**

(74) Representative: **Grünecker, Kinkeldey,**
**Stockmair & Schwanhäusser**
**Anwaltssozietät**
**Maximilianstrasse 58**
**80538 München (DE)**

# (54) LOUVER FIN AND CORRUGATE CUTTER

(57) A louver fin (11) has a corrugated shape by alternately forming bent portions (15) and flat portions (17) in a strip thin sheet (13). In the louver fin (11), a plurality of louvers (19, 21) cut and bent out of the flat portions (17) along the longitudinal direction Y of the strip thin sheet (13) are arranged parallel to each other along the width direction X of the strip thin sheet (13). In the louver fin (11) the louvers (18, 19) are cut and bent at an approximately same angle with respect to the longitudinal direction Y of the strip thin sheet (13).

FIG. 5




EP 1 795 849 A1

## Description

Technical Field

**[0001]** The present invention relates to a radiating louver fin used in a heat exchanger, and a corrugation cutter for forming this louver fin.

Background Art

**[0002]** In cooling devices and air conditioners mounted on vehicles such as automobiles, heat exchangers such as radiators, heater cores, condensers, and evaporators are used. These heat exchangers are configured to exchange with air via a corrugated fin that is formed in a corrugated shape. In recent years, in order to improve heat dissipation performance, a corrugated fin with louvers (hereinafter referred to as a louver fin) has been developed, in which a plurality of louvers that are obliquely open in flat portions (sections between bent portions) of the fin are formed.

**[0003]** Fig. 1 is a perspective view showing the appearance of a typical louver fin. In a louver fin 1, a strip thin sheet 3 is formed in a corrugated shape so that bent portions 3a and flat portions 3b are alternately continued, and that a plurality of louvers 5 having oblique opening directions are formed in each flat portion 3b along the width direction.

**[0004]** The louver fins 1 are classified into bidirectional louver fins and unidirectional louver fins according to the arrangement of the louvers 5 of the flat portions 3b. The louver arrangement of a bidirectional louver fin is shown in Fig. 2. Fig. 2 is a cross-sectional view of the bidirectional louver fin shown in Fig. 1, when is cut in the width direction. In a bidirectional louver fin 1A, the louvers 5 (5a and 5b) formed in one flat portion 3b are formed to be symmetrical to each other so that the opening directions (bending directions) thereof become opposite on the opposite sides of a central portion C1. Further, the louver arrangement of a unidirectional louver fin is shown in Fig. 3. Fig. 3 is a cross-sectional view of an unillustrated unidirectional louver fin, when is cut in the width direction. In a unidirectional louver fin 1B, all the opening directions of the louvers 5 are formed to be in the same direction over the entire area of one flat portion 3b. This unidirectional louver fin 1B has advantages such as higher heat dissipation performance and lower air-flow resistance than those of the bidirectional louver fin 1A.

**[0005]** When the louvers 5 are cut and bent, the material is stretched inward and outward in bottom portions of the louvers, and distortion caused at this time is accumulated around side end portions of the bent portions 3a. In the unidirectional louver fin 1B, the distortion of the louvers 5 which is caused by cutting and bending is distributed in the same direction over the entire side portions. Accordingly, as shown in Fig. 4, a twist occurs in the entire fin due to the distortion, and this causes the fin to curl. If the fin curls in this way after corrugation forming, it becomes impossible to automate the attachment thereof to a heat exchanger core.

**[0006]** Incidentally, in the bidirectional louver fin 1A, since distortion caused when the louvers are cut and bent is brought into balance in the central portion C1, the fin does not curl after corrugation forming.

**[0007]** As a conventional technology for preventing such a unidirectional louver fin from curling after corrugation forming, a corrugated fin is known in which peripheral portions of a strip metal sheet are bent to increase rigidity and to prevent the fin from curling after shaping (JPA 2003-83691).

Disclosure of Invention

**[0008]** However, in a corrugated fin described as the conventional technology, the process of bending peripheral portions of a strip metal sheet is needed, and the fin width needs to be increased by a quantity corresponding to the bending. For this reason, there has been the problem that material yields are decreased.

**[0009]** To solve the above-described problem, it is desired to develop a louver fin having such a shape in which the fin does not curl after corrugation forming, and a corrugation cutter for forming such a louver fin without increasing the number of processes, and without decreasing material yields.

**[0010]** An object of the present invention is to provide a louver fin which does not curl after corrugation forming, and a corrugation cutter.

Brief Description of the Drawings

**[0011]**

[Fig. 1] Fig. 1 is a perspective view showing the appearance of a typical louver fin.
[Fig. 2] Fig. 2 is a cross-sectional view of a bidirectional louver fin, when is cut in the width direction.
[Fig. 3] Fig. 3 is a cross-sectional view of a unidirectional louver fin, when is cut in the width direction.
[Fig. 4] Fig. 4 is a perspective view showing the curling state of a unidirectional louver fin.
[Fig. 5] Fig. 5 is a perspective view showing part of a louver fin according to a first embodiment of the present invention.
[Fig. 6] Fig. 6 is a cross-sectional view taken along line 6-6 of Fig. 5.
[Fig. 7] Fig. 7 is an overall constitution diagram showing a process for manufacturing the louver fin.
[Fig. 8] Fig. 8 is a perspective view showing the arrangement of a corrugation cutter according to the first embodiment.
[Fig. 9] Fig. 9 is an enlarged partial view showing a plurality of tooth portions shown in Fig. 8.
[Fig. 10] Fig. 10 is an exploded perspective view of a corrugation cutter according to the first embodiment of the present invention.

[Fig. 11] Fig. 11 is an enlarged side view of a tooth portion (for one blade) of the corrugation cutter according to the first embodiment of the present invention.

[Fig. 12] Figs. 12A to 12C are cross-sectional views taken along lines 12A-12A, 12B-12B, and 12C-12C of Fig. 11.

[Fig. 13] Fig. 13 is a partial cross-sectional view showing a meshing portion of the corrugation cutter according to the first embodiment of the present invention.

[Fig. 14] Fig. 14 is an enlarged side view showing a tooth portion (for one blade) of a corrugation cutter according to a second embodiment of the present invention.

[Fig. 15] Figs. 15A to 15C are cross-sectional views taken along lines 15A-15A, 15B-15B, and 15C-15C of Fig. 14.

[Fig. 16] Fig. 16 is a perspective view showing the arrangement of the corrugation cutter according to the second embodiment of the present invention.

[Fig. 17] Fig. 17 is an enlarged partial view showing a plurality of tooth portions shown in Fig. 16.

[Fig. 18] Fig. 18 is an exploded perspective view of the corrugation cutter according to the second embodiment of the present invention.

[Fig. 19] Fig. 19 is a perspective view showing part of a louver fin according to the second embodiment of the present invention. [Fig. 20] Fig. 20 is a perspective view showing the arrangement of a corrugation cutter according to a third embodiment of the present invention.

[Fig. 21] Fig. 21 is an enlarged partial view of a plurality of tooth portions shown in Fig. 20.

[Fig. 22] Fig. 22 is an exploded perspective view of the corrugation cutter according to the third embodiment of the present invention.

[Fig. 23] Fig. 23 is a perspective view showing part of a louver fin according to the third embodiment of the present invention. [Fig. 24] Fig. 24 is an enlarged side view of a tooth portion (for one blade) of the corrugation cutter according to the third embodiment of the present invention.

[Fig. 25] Figs. 25A to 25C are cross-sectional views taken along lines 25A-25A, 25B-25B, and 25C-25C of Fig. 24.

[Fig. 26] Fig. 26A is an explanatory diagram showing the arrangement of upper and lower cutters, corresponding to Fig. 25A; Fig. 26B is an explanatory diagram showing the arrangement of the upper and lower cutters, corresponding to Fig. 25B; and Fig. 26C is an explanatory diagram showing the arrangement of the upper and lower cutters, corresponding to Fig. 25C.

[Fig. 27] Fig. 27A is an explanatory cross-sectional view showing a state in which the upper and lower cutters are cutting and bending louvers, corresponding to Fig. 25A; Fig. 27B is an explanatory cross-sectional view showing a state in which the upper and lower cutters are cutting and bending the louvers, corresponding to Fig. 25B; and Fig. 27C is an explanatory cross-sectional view showing a state in which the upper and lower cutters are cutting and bending the louvers, corresponding to Fig. 25C.

Best Mode for Carrying out the Invention

**[0012]** Hereinafter, details of louver fins and corrugation cutters according to embodiments of the present invention will be described with reference to drawings.

FIRST EMBODIMENT

**[0013]** Fig. 5 is a perspective view showing part (corrugated shape for one crest) of a louver fin according to a first embodiment, and Fig. 6 is a cross-sectional view taken along line 6-6 of Fig. 5.

**[0014]** A louver fin 11 described in this embodiment has a continuous corrugated shape obtained by alternately forming bent portions 15 and flat portions 17 in a strip thin sheet 13 made of, for example, an aluminum member. In each flat portion 17, a plurality of louvers 18 or 19 cut and bent along the longitudinal direction Y of the strip thin sheet 13 are arranged parallel to each other along the width direction X of the strip thin sheet 13.

**[0015]** As shown in Fig. 6, these louvers 18 and 19 are formed so that the respective bending directions thereof are aligned with one direction. Further, the bending directions of the louvers 18 and 19 are approximately the same angle $\theta$ along the longitudinal direction Y of the strip thin sheet 13.

**[0016]** Here, a process for manufacturing the louver fin 11 will be briefly described. Fig. 7 is an overall constitution diagram showing the process for manufacturing the louver fin. When the strip thin sheet 13 unwound from a roll 13A passes between a pair of corrugation cutters 21A and 21B (corrugation cutter 21) placed upper and lower positions in the traveling direction, the formation of the bent portions 15 by corrugation forming and the cutting and bending of the louvers 18 and 19 in the flat portions 17 by louver forming are performed at almost the same time. Thereafter, a resistance is applied to the feeding of a corrugated portion by pitch adjusting rolls 23A and 23B, thus reducing the length and adjusting the pitch of the adjacent bent portions 15. Then, the strip thin sheet 13 is fed to a next cutting blade 25 to be cut to a predetermined length. Thus, the louver fin 11 having a length corresponding to the dimensions of a heat exchanger core on which the louver fin 11 is to be mounted is completed.

**[0017]** Next, the structure of a corrugation cutter 21 for shaping the louver fin 11 such as shown in Fig. 5 will be described.

**[0018]** Fig. 8 is a perspective view showing the arrangement of the corrugation cutter 21 shown in Fig. 7. In the corrugation cutter 21 including the pair of (first and

second) corrugation cutters 21A and 21B, one cutter as a male cutter and the other as a female cutter are placed so as to mesh with each other, and are rotationally driven in the directions of arrows by an unillustrated driving mechanism. The structure will be described below primarily by taking the corrugation cutter 21A as an example.

**[0019]** In the corrugation cutter 21A, a plurality of tooth portions 31A are formed radially at a predetermined pitch along the circumferential direction, and apex portions 33 and bottom portions 35 of the tooth portions 31A are alternately formed on the perimeter. As shown in an enlarged partial view of Fig. 9, in each tooth portion 31A, a plurality of cutting and bending edges 39 are formed on one side surface 37, and a plurality of cutting and bending edges 41 are formed on other side surface 37. Thus, the bent portions 15 are consecutively formed in the strip thin sheet 13 at a predetermined pitch by the apex portions 33 and the bottom portions 35 of the tooth portions 31A, and the plurality of louvers 18 and 19 such as shown in Fig. 5 are cut and bent out of the flat portions 17 of the strip thin sheet 13 by the cutting and bending edges 39 and 41 formed on the side surfaces 37 of the tooth portions 31A.

**[0020]** Fig. 10 is an exploded perspective view of the corrugation cutter 21A. The corrugation cutter 21A has a structure in which a predetermined number of thin-plate blades 29 each having a plurality of tooth portions 31A formed radially along the circumferential direction are stacked. In each blade 29, cutting and bending edges 39 and 41 are alternately formed at a predetermined pitch along the circumferential direction. It should be noted that the corrugation cutter 21A may be one formed monolithically.

**[0021]** Similarly in the corrugation cutter 21B., a plurality of tooth portions 31B are formed radially at a predetermined pitch along the circumferential direction, a plurality of cutting and bending edges are formed on one side surface of each tooth portion 31B, and a plurality of cutting and bending edges are formed on other side surface thereof (reference numerals are not shown).

**[0022]** The corrugation cutter 21A configured as described above and the corrugation cutter 21B pairing up therewith are placed so that the respective tooth portions 31A and 31B thereof mesh with each other. By the apex portions 33 of one of the corrugation cutters 21A and 21B meshing with the bottom portions 35 of the other cutter, the bent portions 15 and the flat portions 17 are alternately formed in the strip thin sheet 13. At the same time, by the cutting and bending edges 39 (41) of one cutter meshing with the cutting and bending edges 41 (39) of the other cutter, the louvers 18 and 19 are cut and bent.

**[0023]** Next, the shapes of the cutting and bending edges 39 and 41 formed on the side surfaces 37 of the tooth portions 31B will be described. Fig. 11 is an enlarged side view of the tooth portion 31B (for one blade), and Figs. 12A to 12C are cross-sectional views taken along lines 12A-12A, 12B-12B, and 12C-12C of Fig. 11.

**[0024]** In the corrugation cutter 21B of this embodiment, the edge angles of the cutting and bending edges 39 and 41 are changed so that the angles become smaller in cutting start portions of the louvers 18 and 19 and that the angles become larger in cutting finish portions.

**[0025]** For example, if the direction of shaping the fin is assumed to be the direction of an arrow Z as shown in Fig. 5, the louvers 18 and 19 are cut and bent in the order from a heavy lined arrow ab to a heavy lined arrow cd. Here, let 19a and 19b be cut and bent portions in opposite end portions of the louver 19, and similarly let 18c and 18d be cut and bent portions in opposite end portions of the louver 18. The cut and bent portion 19a is the cutting start portion of the louver 19, and the cut and bent portion 19b is the cutting finish portion. Moreover, the cut and bent portion 18c is the cutting start portion of the louver 18, and the cut and bent portion 18d is the cutting finish portion.

**[0026]** On the other hand, in the corrugation cutter 21B, as shown in Figs. 11 to 12C, the edge angle of the cutting and bending edge 41 for cutting and bending the louver 19 is gradually increased so that the edge angle becomes an edge angle of $\varphi h$ in an edge portion 41h for shaping the cut and bent portion 19a, an edge angle of $\varphi hi$ in an intermediate portion, and an edge angle of $\varphi i$ in an edge portion 41i for shaping the cut and bent portion 19b. Here, these edge angles have the relationship $\varphi i > \varphi hi > \varphi h$, and the edge angle is steplessly changed between edge angles of $\varphi h$ and $\varphi i$.

**[0027]** Further, the edge angle of the cutting and bending edge 39 for cutting and bending the louver 18 is gradually increased so that the edge angle becomes an edge angle of $\varphi j$ in an edge portion 39j for shaping the cut and bent portion 18c, an edge angle of $\varphi jk$ in an intermediate portion, and an edge angle of $\varphi k$ in an edge portion 39k for shaping the cut and bent portion 18d. Here, these edge angles have the relationship $\varphi k > \varphi jk > \varphi j$, and the edge angle is steplessly changed between edge angles of $\varphi k$ and $\varphi j$ .

**[0028]** It should be noted that, with regard to the directions of forming the cutting and bending edges 39 and 41, as shown in Figs. 12A to 12C, cutting surfaces of the edges are formed to face opposite directions on the side surfaces 37 positioned on opposite sides of the apex portion 33 of one tooth portion 31B.

**[0029]** On the other hand, the corrugation cutter 21A pairing up with the corrugation cutter 21B is also formed in about the same shape. The edge angles of the cutting and bending edges are changed so that the angles become smaller in cutting start portions of the louvers 18 and 19 and that the angles become larger in cutting finish portions. Fig. 13 is a partial cross-sectional view showing the meshing portion between the corrugation cutters 21A and 21B. Each cutting and bending edge of the corrugation cutter 21B is paired with the cutting and bending edge 39 (41) of the corrugation cutter 21A so that the directions and angles of the edges become mirror symmetric when they are meshed with each other.

**[0030]** Generally, in louver forming using corrugation cutters, the edge angles φ of the cutting and bending edges 39 and 41 determine the bending angles of the louvers 18 and 19. That is, the bending angles become larger in portions in which the edge angles φ are large, and the bending angles become smaller in portions in which the edge angles φ are small. In usual louver forming, cutting and bending are neatly performed in a portion (cutting start portion) cut and bent first. However, in a portion (cutting finish portion) cut and bent later, cutting and bending are not neatly performed. Accordingly, bending angles differ between cut and bent portions at opposite ends of one louver, and distortion occurs in the louver.

**[0031]** On the other hand, in the corrugation cutter 21A (21B) of this embodiment, the edge angles of the cutting and bending edges 39 and 41 become smaller in cutting start portions of louvers, and become larger in cutting finish portions. Accordingly, in the cutting start portions neatly cut and bent, shaping is performed so that the bending angles do not become larger; and, in the cutting finish portions not neatly cut and bent, shaping is performed so that the bending angles become larger. Accordingly, as shown in Fig. 5, shaping can be performed so that the bending angles in the cut and bent portions 18c, 18d, 19a, and 19b at both ends of the louvers 18 and 19 become approximately equal. Thus, since the bending angles in the cut and bent portions at both ends of the louvers become approximately equal, there is no distortion in the louvers, and a twist of the entire fin due to distortion can be prevented. Therefore, a warp in the louver fin 11 after shaping can be prevented.

**[0032]** Accordingly, in the corrugation cutter 21 described in this embodiment, there is no need for the process of bending peripheral portions of the strip thin sheet 13 in order to prevent a twist, and there is also no need for increasing the fin width by a quantity corresponding to the bending. Thus, a unidirectional louver fin which does not warp after corrugation forming can be obtained without increasing the number of manufacturing processes and decreasing material utilization.

**[0033]** It should be noted that for the edge angles of the cutting and bending edges 39 and 41, optimum values are individually found according to the shape and material of the fin. These values can be determined by performing an experiment or a simulation.

## SECOND EMBODIMENT

**[0034]** Next, a corrugation cutter according to a second embodiment of the present invention will be described.

**[0035]** As a technology relating to the machining of a corrugation cutter such as shown in the aforementioned first embodiment, a method is known in which an inclined edge surface of a cutter is ground at an angle so as to match the grinding surface of a grinding stone (see JPA 1-2833) . However, in the machining method described in JPA 1-2833, since an inclined edge can be machined only at a constant edge angle, it is technically difficult to manufacture a corrugation cutter (gradual-change corrugation cutter) according to the aforementioned first embodiment in which an edge angle gradually changes. Further, a gradual-change corrugation cutter can be machined by machining an inclined edge by means other than a grinding process using a grinding stone, such as a cutting process or a discharge process. However, since a cutting process is inferior in the surface roughness of a machined surface to a grinding process, fin shaping may be adversely affected. Further, a discharge process takes more machining time than a grinding process, and therefore causes an increase in cost.

**[0036]** In view of this, in the second embodiment, a corrugation cutter is provided which has functions equivalent to those of the corrugation cutter that can form the louver fin according to the first embodiment and that have edge angles gradually changing, and which can be manufactured by a grinding process.

**[0037]** First, the basic structure of the corrugation cutter according to the second embodiment will be described using Figs. 16 to 18. Fig. 16 is a perspective view showing the arrangement of the corrugation cutter. Fig. 17 is an enlarged partial view of tooth portions. Fig. 18 is an exploded perspective view of the corrugation cutter. Fig. 19 is a perspective view showing part (corrugated shape for one crest) of a louver fin.

**[0038]** As shown in Fig. 16, a corrugation cutter 121 includes a pair of (first and second) corrugation cutters 121A and 121B. The corrugation cutters 121A and 121B are placed so that one as a male cutter and the other as a female cutter mesh with each other, and are rotationally driven in the directions of arrows by an unillustrated driving mechanism. The following description will be given by taking the corrugation cutter 121A as an example.

**[0039]** In the corrugation cutter 121A, a plurality of tooth portions 131A are formed radially at a predetermined pitch along the circumferential direction, and apex portions 133 and bottom portions 135 of the tooth portions 131A are alternately formed on the perimeter. As shown in Fig. 17, in each tooth portion 131A, a plurality of cutting and bending edges (shapes of the edges are not shown) 139 are formed on one side surface 137a, and a plurality of cutting and bending edges (shapes of the edges are not shown) 141 are formed on other side surface 137b.

**[0040]** As shown in Fig. 18, the corrugation cutter 121A has a structure in which a predetermined number of thin-plate blades 129 each having a plurality of tooth portions 131A formed radially along the circumferential direction are stacked. In each blade 129, cutting and bending edges 139 and 141 are alternately formed at a predetermined pitch along the circumferential direction. It should be noted, however, that the corrugation cutter is not limited to a structure in which a plurality of members are stacked, and may be one formed monolithically.

**[0041]** Similarly, in the corrugation cutter 121B, a plurality of tooth portions 131B are formed radially at a predetermined pitch along the circumferential direction, a

plurality of cutting and bending edges are formed on one side surface of each tooth portion 131B, and a plurality of cutting and bending edges are formed on other side surface thereof (reference numerals are not shown).

**[0042]** As shown in Fig. 16, when the corrugation cutter 121A having the above-described cutting and bending edges 139 and 141 formed therein and the corrugation cutter 121B having cutting and bending edges formed therein which have the same structures are meshed with each other and rotationally driven, and a strip thin sheet 113 is supplied between these cutters, the apex portions 133 of one corrugation cutter mesh with the bottom portions 135 of the other corrugation cutter, and bent portions 115 and flat portions 117 are alternately formed in the strip thin sheet 113 such as shown in Fig. 19. At the same time, by the cutting and bending edges 139 (141) of one corrugation cutter meshing with the cutting and bending edges 139 (141) of the other corrugation cutter, a plurality of louvers 118 and 119 are cut and bent out of the flat portions 117 of the strip thin sheet 113, thus obtaining a louver fin 111.

**[0043]** Next, the shapes of the cutting and bending edges 139 and 141 formed on the side surfaces 137a and 137b of the tooth portions 131A (131B) will be described. Fig. 14 is an enlarged partial view showing the shapes of side surfaces of adjacent tooth portions 131B. Figs. 15A to 15C are cross-sectional views taken along lines 15A-15A, 15B-15B, and 15C-15C of Fig. 14, showing the mesh of cutting and bending edges, and showing a virtual cross section at the time when the corrugation cutters 121A and 121B mesh with each other.

**[0044]** In the corrugation cutter 121B of this embodiment, as shown in Fig. 14, the cutting and bending edge 139 provided on one side surface 137a of the tooth portion 131B is shaped (ground down) so that an edge height h1 becomes smallest in an apex-side edge portion 139a for machining the cutting start portion of the louver 118, that an edge height h2 becomes largest in a bottom-side edge portion 139a for machining the cutting finish portion of the louver 118, and that the edge height continuously increases from the apex-side edge portion 139a toward the bottom-side edge portion 139b.

**[0045]** Here, as shown in Fig. 19, a louver 118 is cut and bent in the direction of an arrow from a cutting start portion 118a toward a cutting finish portion 118b, and a louver 119 is cut and bent in the direction of an arrow from a cutting start portion 119c toward a cutting finish portion 119d (the direction of shaping the fin is assumed to be the direction of an arrow a). The edge heights h1 and h2 are represented as heights from a chain line showing the shape of an original gear. It should be noted that a two-dot chain line indicates an edge height before the edge heights h1 and h2 are provided in this embodiment. That is, the two-dot chain line indicates a shape obtained by attaching an edge to the shape of the original gear.

**[0046]** Accordingly, the cross sections of the cutting and bending edge 139 are the same from the apex-side edge portion 139a to the bottom-side edge portion 139b. However, in this embodiment, by continuously cutting down the edge height of the cutting and bending edge 139 from the position of the two-dot chain line, the thickness t (land width) of the cutting and bending edge 139 in the width direction thereof gradually decreases from the apex-side edge portion 139a toward the bottom-side edge portion 139b.

**[0047]** Further, an inclined edge 140 is shaped at the same edge angle $\theta$ from the apex-side edge portion 139a to the bottom-side edge portion 139b. The two-dot chain line shown in Fig. 14 indicates a line for the case where shaping is performed at the edge angle $\theta$ from the apex-side edge portion 139a to the bottom-side edge portion 139b. In this embodiment, since the edge height is continuously cut down from the apex-side edge portion 139a toward the bottom-side edge portion 139b, the range outside the solid line of the cutting and bending edge 139 indicates a region in which the inclined edge 140 is not actually machined.

**[0048]** Moreover, a cutting and bending edge 141 provided on the other side surface 137b of the tooth portion 131B is shaped (ground down) so that the edge height h1 is smallest in a bottom-side edge portion 141a for machining the cutting start portion 119c of the louver 119 shown in Fig. 19, that the edge height h2 is largest in an apex-side edge portion 141b for machining the cutting finish portion 119d of the louver 119, and that the edge height continuously increases from the apex-side edge portion 141a toward the bottom-side edge portion 141b.

**[0049]** Accordingly, the cross section of the cutting and bending edge 141 is the same from the bottom-side edge portion 141a to the apex-side edge portion 141b. However, in this embodiment, by continuously cutting down the edge height of the cutting and bending edge 141 from the position of the two-dot chain line, the thickness t (land width) of the cutting and bending edge 141 in the width direction thereof gradually decreases from the bottom-side edge portion 141a toward the apex-side edge portion 141b.

**[0050]** Further, an inclined edge 142 is shaped at the same edge angle $\theta$ from the bottom-side edge portion 141a to the apex-side edge portion 141b. The two-dot chain line shown in Fig. 14 indicates a line for the case where shaping is performed at the edge angle $\theta$ from the bottom-side edge portion 141a to the apex-side edge portion 141b. In this embodiment, since the edge height is continuously cut down from the bottom-side edge portion 141a toward the apex-side edge portion 141b, the range outside the solid line of the cutting and bending edge 141 indicates a region in which the inclined edge 142 is not actually machined.

**[0051]** In the tooth portions 131A of the corrugation cutter 121A pairing up with the above-described corrugation cutter 121B, cutting and bending edges (hereinafter denoted by 139A and 141A) similar to those of the tooth portions 131B are formed. Further, when the corrugation cutters 121A and 121B are meshed with each other, the cutting and bending edges 139 provided on

the side surfaces 137a of the tooth portions 131B of the corrugation cutter 121B face the cutting and bending edges 139A provided on the side surfaces 137a of the tooth portions 131A of the corrugation cutter 121A, and the cutting and bending edges 141 provided on the side surfaces 137b of the tooth portions 131B of the corrugation cutter 121B face the cutting and bending edges 141A provided on the side surfaces 137b of the tooth portions 131A of the corrugation cutter 121A. Thus, each cutting and bending edge 139 (141) of the corrugation cutter 121B is paired with the cutting and bending edge 139A (141A) of the corrugation cutter 121A so that the directions and angles of the edges become mirror symmetric when they are meshed with each other.

**[0052]** Next, the action of the corrugation cutter 121 according to this embodiment will be described. Here, a description will be given for the case where the louver 119 is cut and bent in the direction of an arrow from the cutting start portion 119c toward the cutting finish portion 119d in Fig. 19.

**[0053]** In the machining of the cutting start portion 119c of the louver 119, as shown in Fig. 15A which is a cross section taken along line 15A-15A of Fig. 14, the flat portion 117 of the strip thin sheet 113 is cut and bent between the bottom-side edge portion 141a of the cutting and bending edge 141 of the corrugation cutter 121B and the apex-side edge portion 141b of the cutting and bending edge 141A of the corrugation cutter 121A. At this time, the flat portion 117 is cut and bent at a bending angle of φa along the line connecting a corner portion 142b of the inclined edge (hereinafter referred to as an upper inclined edge) 142 of the corrugation cutter 121A and a corner portion 142a of the inclined edge (hereinafter referred to as a lower inclined edge) 142 of the corrugation cutter 121B.

**[0054]** In the machining of an intermediate cut and bent portion 119cd of the louver 119, as shown in Fig. 15B which is a cross section taken along line 15B-15B of Fig. 14, the flat portion 117 of the strip thin sheet 113 is cut and bent between an intermediate edge portion 141ab of the cutting and bending edge 141 of the corrugation cutter 121B and an intermediate edge portion 141a of the corrugation cutter 121A. At this time, the flat portion 117 is cut and bent at a bending angle of φb along the line connecting a corner portion 142ab of the upper inclined edge 142 and a corner portion 142ab of the lower inclined edge 142.

**[0055]** In the machining of a cutting finish portion 119d of the louver 119, as shown in Fig. 15C which is a cross section taken along line 15C-15C of Fig. 14, the flat portion 117 of the strip thin sheet 113 is cut and bent between the apex-side edge portion 141b of the cutting and bending edge 141 of the corrugation cutter 121B and the bottom-side edge portion 141a of the cutting and bending edge 141A of the corrugation cutter 121A. At this time, the flat portion 117 is cut and bent at a bending angle of φc along the line connecting a corner portion 141a of the upper inclined edge 142 and a corner portion 142b of the lower inclined edge 142.

**[0056]** As described above, in the corrugation cutters 121A and 121B of this embodiment, since the width-direction thicknesses t of the cutting and bending edges 139 and 141 gradually changes from t1 to t3 (t1>t2>t3) while the edge angles θ thereof are made constant, the bending angles of the inclined edges 140 and 142 also change continuously. Accordingly, the louvers formed in the strip thin sheet 113 are shaped so that the bending angles φ become smaller (φa) in cutting start portions and that the bending angles φ become larger (φc) in cutting finish portions.

**[0057]** Generally, in louver forming using corrugation cutters, the edge angles φ of the cutting and bending edges 139 and 141 determine the bending angles of louvers. That is, the bending angles φ become larger when machining is performed using portions in which the edge angles θ are large, and the bending angles φ become smaller when machining is performed using portions in which the edge angles θ are small. In usual louver forming, cutting and bending are neatly performed in a portion (cutting start portion) cut and bent first. However, in a portion (cutting finish portion) cut and bent later, cutting and bending are not neatly performed. Accordingly, bending angles differ between opposite ends of one louver, and distortion occurs in the louver.

**[0058]** On the other hand, with the corrugation cutters 121A (121B) of this embodiment, the bending angle φ becomes smaller (φa) in the cutting start portion of a louver and becomes larger (φc) in the cutting finish portion. Accordingly, as in the case where shaping is performed using a gradual-change corrugation cutter, in the cutting start portion neatly cut and bent originally, shaping is performed so that the bending angle does not become larger; and, in the cutting finish portion not neatly cut and bent, shaping is performed so that the bending angle becomes larger. Accordingly, as shown in Fig. 19, the bending angles φ in the cutting start portion 118a and the cutting finish portion 118b of the louver 118 and those in the cutting start portion 119c and the cutting finish portion 119d of the louver 119 can be made approximately equal after shaping. Thus, since the bending angles in opposite end portions of the louvers 118 and 119 shaped in one direction are made approximately equal, there is no distortion in the louvers, and a twist of the entire fin due to distortion can be prevented. Therefore, a warp in the louver fin 111 after shaping can be prevented.

**[0059]** Moreover, in the corrugation cutters 121A and 121B of this embodiment, since the edge angles θ can be made constant, a corrugation cutter can be manufactured which has functions equivalent to those of the gradual-change corrugation cutter according to the aforementioned first embodiment. According to this second embodiment, since the inclined edges 140 and 142 are machined by not a cutting process but a grinding process, the surface roughness of machined surfaces can be made equivalent to that of current ones, and adverse affects on fin shaping can be avoided. Further, unlike a

discharge process, a long machining time is not required. Therefore, an increase in cost can be avoided.

**[0060]** It should be noted that for the edge heights and edge angles of the cutting and bending edges 139 and 141, optimum values are individually found according to the shape and material of the fin. These values can be determined by performing an experiment or a simulation.

THIRD EMBODIMENT

**[0061]** Next, a corrugation cutter according to a third embodiment of the present invention will be described.

**[0062]** In the machining method described in the aforementioned JPA 1-2833, since an inclined edge can be machined only at a constant edge angle, it is technically difficult to manufacture a corrugation cutter (gradual-change corrugation cutter) according to the aforementioned first embodiment in which an edge angle gradually changes. Further, a gradual-change corrugation cutter can be machined by machining an inclined edge by means other than a grinding process using a grinding stone, such as a cutting process or a discharge process. However, since a cutting process is inferior in the surface roughness of a machined surface to a grinding process, fin shaping may be adversely affected. Further, a discharge process takes more machining time than a grinding process, and therefore causes an increase in cost.

**[0063]** In view of this, in the third embodiment, a corrugation cutter is provided which has functions equivalent to those of the corrugation cutter according to the aforementioned first embodiment having edge angles gradually changing, and which can be manufactured by a grinding process.

**[0064]** First, the basic structure of the corrugation cutter according to the third embodiment will be described using Figs. 20 to 23. Fig. 20 is a perspective view showing the arrangement of the corrugation cutter. Fig. 21 is an enlarged partial view of tooth portions. Fig. 22 is an exploded perspective view of the corrugation cutter. Fig. 23 is a perspective view showing part (corrugated shape for one crest) of a louver fin.

**[0065]** As shown in Fig. 20, a corrugation cutter 221 includes a pair of (first and second) corrugation cutters 221A and 221B. The corrugation cutters 221A and 221B are placed so that one as a male cutter and the other as a female cutter mesh with each other, and are rotationally driven in the directions of arrows by an unillustrated driving mechanism. The following description will be given by taking the corrugation cutter 221A as an example.

**[0066]** In the corrugation cutter 221A, a plurality of tooth portions 231A are formed radially at a predetermined pitch along the circumferential direction, and apex portions 233 and bottom portions 235 of the tooth portions 231A are alternately formed on the perimeter. As shown in Fig. 21, in each tooth portion 231A, a plurality of cutting and bending edges (shapes of the edges are not shown) 239 are formed on one side surface 237a, and a plurality of cutting and bending edges (shapes of the edges are not shown) 241 are formed on other side surface 237b.

**[0067]** As shown in Fig. 22, the corrugation cutter 221A has a structure in which a predetermined number of thin-plate blades 229 each having a plurality of tooth portions 231A formed radially along the circumferential direction are stacked. In each blade 229, cutting and bending edges 239 and 241 are alternately formed at a predetermined pitch along the circumferential direction. It should be noted, however, that the corrugation cutter is not limited to a structure in which a plurality of members are stacked, and may be one formed monolithically.

**[0068]** Similarly, in the corrugation cutter 221B, a plurality of tooth portions 231B are formed radially at a predetermined pitch along the circumferential direction, a plurality of cutting and bending edges are formed on one side surface of each tooth portion 231B, and a plurality of cutting and bending edges are formed on other side surface thereof (reference numerals are not shown).

**[0069]** When the corrugation cutter 221A having the above-described cutting and bending edges 239 and 241 formed therein and the corrugation cutter 221B having cutting and bending edges formed therein which have the same structures are meshed with each other and rotationally driven, and a strip thin sheet 213 is supplied between these cutters as shown in Fig. 20, the apex portions 233 of one corrugation cutter mesh with the bottom portions 235 of the other corrugation cutter, and bent portions 215 and flat portions 217 such as shown in Fig. 23 are alternately formed in the strip thin sheet 213. At the same time, by the cutting and bending edges 239 (241) of one corrugation cutter meshing with the cutting and bending edges 239 (241) of the other corrugation cutter, a plurality of louvers 218 and 219 are cut and bent out of the flat portions 217 of the strip thin sheet 213, thus obtaining a louver fin 211.

**[0070]** Next, the shapes of the cutting and bending edges 239 and 241 formed on the side surfaces 237a and 237b of each tooth portion 231A (231B) will be described. Fig. 24 is an enlarged partial view showing the shapes of side surfaces of adjacent tooth portions 231B. Figs. 25A to 25C are cross-sectional views taken along lines 25A-25A, 25B-25B, and 25C-25C of Fig. 24, showing the mesh of cutting and bending edges, and showing a virtual cross section at the time when the corrugation cutters 221A and 221B mesh with each other.

**[0071]** It should be noted that Fig. 26A shows a state in which cutting and bending edges start cutting the louver 219, and a cross section of the mesh thereof corresponds to Fig. 25A. Fig. 26B shows a state in which the cutting and bending edges are cutting an intermediate portion 219cd of the louver 219, and a cross section of the mesh thereof corresponds to Fig. 25B. Fig. 26C shows a state in which the cutting and bending edges are cutting a cutting and bending finish portion 219d of the louver 219, and a cross section of the mesh thereof corresponds to Fig. 25C. Moreover, Figs. 27A to 27C are views showing the states of the flat portion 217 actually cut and bent by the corrugation cutters 221A and 221B

at mesh positions corresponding to Figs. 25A to 25C, respectively.

**[0072]** In the corrugation cutter 221B of this embodiment, as shown in Fig. 24, the cutting and bending edge 239 provided on one side surface 237a of the tooth portion 231B is set so that the thickness (land width) of the edge in the width direction thereof becomes equal between an apex-side edge portion 239a for machining a cutting start portion 218a of the louver 218 shown in Fig. 23 and a bottom-side edge portion 239b for machining the cutting finish portion 218b of the louver 218. As shown in Fig. 24, the cutting and bending edges 239 and 241 are formed so that the angles and land widths of inclined edges are made constant from the apex-side edge portions to the bottom-side edge portions, and the lengths (portions denoted by ha, hb, and hc) vary by which the inclined edges protrude from the portions indicated by chain lines.

**[0073]** Here, as shown in Fig. 23, the louver 218 is cut and bent in the direction of an arrow from the cutting start portion 218a toward the cutting finish portion 218b, and the louver 219 is cut and bent in the direction of an arrow from the cutting start portion 219c toward the cutting finish portion 219d (the direction of shaping the fin is assumed to be the direction of an arrow a).

**[0074]** In this embodiment, as shown in Figs. 25A to 25C, inclined edges 240 and 242 are formed so that the edge angles of the cutting and bending edges 239 and 241 of the corresponding tooth portions 231A and 231B of the corrugation cutters 221A and 221B are the same angle $\theta$ over the longitudinal directions of the edges. These inclined edges 240 and 242 are formed by being ground down. Further, the edges denoted by the same reference numeral of the inclined edges 240 and 242 of the cutting and bending edges 239 and 241 are set so as to be parallel to each other with a predetermined clearance c provided therebetween in a state in which they mesh with each other.

**[0075]** Hereinafter, the clearance c will be described with reference to Figs. 24 to 27C.

**[0076]** This clearance c is set so that the distance between the inclined edges 240 becomes a large clearance c1 as shown in Fig. 25A at a position (see Fig. 26A) 241a at which the louver 219 starts being cut. The flat portion 217 to be cut and bent is cut and bent at a bending angle of $\varphi$a along the line connecting a corner portion 242a of the inclined edge (hereinafter referred to as an upper inclined edge) 242 of the corrugation cutter 221A and a corner portion 242a of the inclined edge (hereinafter referred to as a lower inclined edge) 242 of the corrugation cutter 221B.

**[0077]** Next, in the machining of the intermediate cut and bent portion 219cd of the louver 219, as shown in Fig. 25B which is a cross-sectional view taken along line 25B-25B at a position 241ab of Fig. 24, an intermediate-level clearance c2 is set. Further, the flat portion 217 of the strip thin sheet 213 is cut and bent between an intermediate edge portion 241ab of the cutting and bending edge 241 of the corrugation cutter 221B and an intermediate edge portion 241ab of the corrugation cutter 221A. At this time, the flat portion 217 is cut and bent at a bending angle of $\varphi$b along the line connecting a corner portion 242ab of the upper inclined edge 242 and a corner portion 242ab of the lower inclined edge 242.

**[0078]** Next, in the machining of the cutting and bending end point position 219d of the louver 219, as shown in Fig. 25 which is a cross-sectional view taken along line 25C-25C at a position 241b of Fig. 24, a small clearance c3 is set. Further, as shown in Fig. 25C, the flat portion 217 of the strip thin sheet 213 is cut and bent between an end-point-side edge portion 241b of the cutting and bending edge 241 of the corrugation cutter 221B and an edge portion 241a of the corrugation cutter 221A. At this time, the flat portion 217 is cut and bent at a bending angle of $\varphi$c along the line connecting a corner portion 242a of the upper inclined edge 242 and a corner portion 242b of the lower inclined edge 242. In this way, in the cutting and bending edges of the corrugation cutter of this embodiment, the clearances cl, c2, and c3 are determined by the protruding quantities (ha, hb, and hc) of the inclined edges.

**[0079]** Next, the action of the corrugation cutter 221 according to this embodiment will be described. Here, a description will be given for the case where the louver 219 is cut and bent in the direction of an arrow from the cutting start portion 219c toward the cutting finish portion 219d in Fig. 23.

**[0080]** In the machining of the cutting start portion 219c of the louver 219, as shown in Fig. 25A which is a cross section taken along line 25A-25A of Fig. 24, the flat portion 217 of the strip thin sheet 213 is cut and bent between the bottom-side edge portion 241a of the cutting and bending edge 241 of the corrugation cutter 221B and the edge portion 241b of the corrugation cutter 221A. At this time, the flat portion 217 of the strip thin sheet 213 is cut and bent at a bending angle of $\varphi$a with the clearance c1 along the line connecting the corner portion 242b of the upper inclined edge 242 and the corner portion 242a of the lower inclined edge 242.

**[0081]** In the machining of the intermediate cut and bent portion 219cd of the louver 219 shown in Fig. 23, as shown in Fig. 25B which is a cross section taken along line 25B-25B of Fig. 24, the flat portion 217 of the strip thin sheet 213 is cut and bent between the intermediate edge portion 241ab of the cutting and bending edge 241 of the corrugation cutter 221B and the intermediate edge portion 241ab of the corrugation cutter 221A. At this time, the flat portion 217 is cut and bent at a bending angle of $\varphi$b with a clearance of c2 along the line connecting the corner portion 242ab of the upper inclined edge 242 and the corner portion 242ab of the lower inclined edge 242.

**[0082]** In the machining of the cutting finish portion 219d of the louver 219, as shown in Fig. 25C which is a cross section taken along line 25C-25C of Fig. 24, the flat portion 217 of the strip thin sheet 213 is cut and bent between the apex-side edge portion 241b of the cutting

and bending edge 241 of the corrugation cutter 221B and the edge portion 241a of the corrugation cutter 221A. At this time, the flat portion 217 is cut and bent at a bending angle of φc with clearance c3 along the line connecting the corner portion 242a of the upper inclined edge 242 and the corner portion 242b of the lower inclined edge 242.

**[0083]** As described above, in the corrugation cutters 221A and 221B of this embodiment, since only the clearance c is gradually changed (c3<c2<c1) while the edge angles θ of the cutting and bending edges 239 and 241 are made constant as shown in Figs. 25A to 25C, the bending angles of the inclined edges 240 and 242 also change continuously. Accordingly, the louvers formed in the strip thin sheet 213 are shaped so that the bending angles φ become smaller (φa) in cutting start portions and that the bending angles φ become larger (φc) in cutting finish portions.

**[0084]** Generally, in louver forming using corrugation cutters, the edge angles θ of the cutting and bending edges 239 and 241 determine the bending angles of louvers. That is, the bending angles φ become larger when machining is performed using portions in which the edge angles θ are large, and the bending angles φ become smaller when machining is performed using portions in which the edge angles θ are small. In usual louver forming, cutting and bending are neatly performed in a portion (cutting start portion) cut and bent first. However, in a portion (cutting finish portion) cut and bent later, cutting and bending are not neatly performed. Accordingly, bending angles differ between opposite ends of one louver, and distortion occurs in the louver.

**[0085]** On the other hand, with the corrugation cutters 221A (221B) of this embodiment, the bending angle φ becomes smaller (φa) in the cutting start portion of a louver and becomes larger (φc) in the cutting finish portion. Accordingly, as in the case where shaping is performed using a gradual-change corrugation cutter, in the cutting start portion neatly cut and bent performed originally, shaping is performed so that the bending angle does not become larger; and, in the cutting finish portion not neatly cut and bent, shaping is performed so that the bending angle becomes larger. Accordingly, as shown in Fig. 23, the bending angles in the cutting start portion 218a and the cutting finish portion 218b of the louver 218 and those in the cutting start portion 219c and the cutting finish portion 219d of the louver 219 can be made approximately equal after shaping. Thus, since the bending angles in opposite end portions of the louvers 218 and 219 shaped in one direction are made approximately equal, there is no distortion in the louvers, and a twist of the entire fin due to distortion can be prevented. Therefore, a warp in the louver fin 211 after shaping can be prevented.

**[0086]** Moreover, in the corrugation cutters 221A and 221B of this embodiment, since the edge angles θ can be made constant, a corrugation cutter can be easily manufactured which has functions equivalent to those of the corrugation cutter according to the aforementioned first embodiment. According to this third embodiment, since the inclined edges 240 and 242 are machined by not a cutting process but a grinding process, the surface roughness of machined surfaces can be made equivalent to that of current ones, and adverse affects on fin shaping can be avoided. Further, unlike a discharge process, a long machining time is not required. Therefore, an increase in cost can be avoided.

**[0087]** It should be noted that for the edge heights and edge angles of the cutting and bending edges 239 and 241, optimum values are individually found according to the shape and material of the fin. These values can be determined by performing an experiment or a simulation.

Industrial Applicability

**[0088]** Corrugation cutters according to the present invention can be applied to heat exchangers including a radiator mounted on a vehicle such as an automobile, and a heater core, a condenser, an evaporator, and the like used in an air conditioner, and are useful particularly in manufacturing a unidirectional louver fin suitable for these heat exchangers.

**Claims**

**1.** A louver fin **characterized by** comprising:

a plurality of flat portions which are made of a strip thin sheet, and in each of which a plurality of louvers are cut and bent along a longitudinal direction of the strip thin sheet, are arranged parallel to each other along a width direction of the strip thin sheet, and are formed so that bending angles of the louvers become approximately the same with respect to the longitudinal direction of the strip thin sheet; and

a bent portion serving as a boundary between the flat portions and being a portion for coupling the flat portions so that the plurality of flat portions form a corrugated shape.

**2.** A corrugation cutter **characterized by** comprising:

a pair of cutters in each of which a plurality of tooth portions are formed along a circumferential direction, and which are combined to mesh with each other; and

**characterized in that**:

a corrugated fin with louvers is formed by forming alternately bent portions and flat portions in a strip thin sheet, which is supplied between the pair of cutters, at a predetermined pitch by using apex portions and bottom portions of the tooth portions facing each other, and by cutting and bending a plurality of louvers out of the flat portions of the strip thin sheet by using a plurality

of cutting and bending edges provided on side surfaces of the tooth portions; and that
an edge angle of the cutting and bending edge provided on a side surface of each of the tooth portions changes along a longitudinal direction of the strip thin sheet so that the angle becomes smaller in a cutting start portion of one of the louvers and that the angle becomes larger in a cutting,finish portion thereof.

**3.** A corrugation cutter **characterized by** comprising:

a first cutter in which a plurality of first tooth portions having triangular shapes are formed along a circumferential direction, in which a plurality of first cutting and bending edges for cutting and bending louvers in a strip thin sheet are provided on side surfaces in the circumferential direction of each of the first tooth portions, and in which an edge angle of each of the first cutting and bending edges gradually changes along longitudinal directions of the first cutting and bending edges so that the angle becomes smaller in a cutting start portion of one of the louvers, and that the angle becomes larger in a cutting finish portions thereof; and
a second cutter which is rotationally driven in synchronization with the first cutter so as to mesh with the first cutter; in which a plurality of second tooth portions are formed along a circumferential direction; in which the second tooth portions alternately form bent portions and flat portions machine the strip thin sheet into a corrugated shape in conjunction with the first tooth portions by alternately forming bent portions and flat portions of the strip thin sheet; in which a plurality of second cutting and bending edges for cutting and bending the louvers in the strip thin sheet in conjunction with the first tooth portions are provided on the side surfaces in the circumferential direction of the second tooth portions; and in which an edge angle of each of the second cutting and bending edges gradually changes along longitudinal directions of the cutting and bending edges so that the angle becomes smaller in the cutting start portion of one of the louvers, and that the angle becomes larger in the cutting finish portion thereof.

**4.** A corrugation cutter **characterized by** comprising a pair of cutters in each of which a plurality of tooth portions are radially formed, and which are placed to face each other at a predetermined distance, **characterized in that**:

a corrugated fin with louvers is formed by forming alternately bent portions and flat portions in a strip thin sheet, which is supplied between the pair of cutters by using apex portions and bottom portions of the tooth portions facing each other, and by cutting and bending a plurality of louvers out of the flat portions of the strip thin sheet by using a plurality of cutting and bending edges provided on side surfaces of the tooth portions; the cutting and bending edge provided on one side surface of each tooth portion is formed with an edge height which continuously increases from the apex-side edge portions toward the bottom-side edge portions, and which becomes smallest in an apex-side edge portion for machining a cutting start portion of one of the louvers, and becomes largest in a bottom-side edge portion for machining a cutting finish portion thereof, the cutting and bending edge including an inclined edge having an edge angle $\theta$ formed from the apex-side edge portions to the bottom-side edge portions; and that
the cutting and bending edge provided on the other side surface of each tooth portion is formed with an edge height which continuously increases from the apex-side edge portions toward the bottom-side edge portions, and which becomes smallest in a bottom-side edge portion for machining the cutting start portion of the louver, and becomes largest in apex-side edge portions for machining the cutting finish portion thereof, and the cutting and bending edge including an inclined edge having an edge angle $\theta$ formed from the bottom-side edge portions to the apex-side edge portions.

**5.** A corrugation cutter **characterized by** comprising:

a first cutter in which a plurality of first tooth portions are formed along a circumferential direction, in which a plurality of first cutting and bending edges for cutting and bending louvers in a strip thin sheet are provided on side surfaces in the circumferential direction of each of the first tooth portions, and in which an edge height of each of the first cutting and bending edges gradually changes along longitudinal directions of the first cutting and bending edges so that the height becomes smallest in a cutting start portion of one of the louvers, and become largest in a cutting finish portion thereof; and
a second cutter which is rotationally driven in synchronization with the first cutter so as to mesh with the first cutter; in which a plurality of second tooth portions are formed along a circumferential direction; in which the second tooth portions machine the strip thin sheet into a corrugated shape in conjunction with the first tooth portions by alternately forming bent portions and flat portions of the strip thin sheet; in which a plurality of second cutting and bending edges

for cutting and bending the louvers in the strip thin sheet in conjunction with the first tooth portions are provided on the side surfaces in the circumferential direction of the second tooth portions; and in which an edge height of each of the second cutting and bending edges gradually changes along longitudinal directions of the second cutting and bending edge so that the height becomes smallest in the cutting start portion of the louver, and becomes largest in the cutting finish portion thereof.

**6.** A corrugation cutter **characterized by** comprising:

a first cutter in which a plurality of first tooth portions are formed along a circumferential direction, and in which a plurality of first cutting and bending edges for cutting and bending louvers in a strip thin sheet are provided on side surfaces in the circumferential direction of the first tooth portions, and in which an edge angle $\theta$ of each of the first cutting and bending edges is constant along longitudinal directions thereof; and
a second cutter which is rotationally driven in synchronization with the first cutter so as to mesh with the first cutter; in which a plurality of second tooth portions are formed along a circumferential direction; in which the second tooth portions machine the strip thin sheet into a corrugated shape in conjunction with the first tooth portions, by alternately forming bent portions and flat portions of the strip thin sheet; in which a plurality of second cutting and bending edges for cutting and bending the louvers in the strip thin sheet in conjunction with the first tooth portions are provided on side surfaces of the second tooth portions in the circumferential direction; in which an edge angle $\theta$ of each of the second cutting and bending edges is constant along longitudinal directions thereof; and in which a clearance between the first cutting and bending edge and the second cutting and bending edge gradually changes relatively to be largest in a cutting start portion of one of the louvers and to be smallest in a cutting finish portion thereof.

FIG. 1

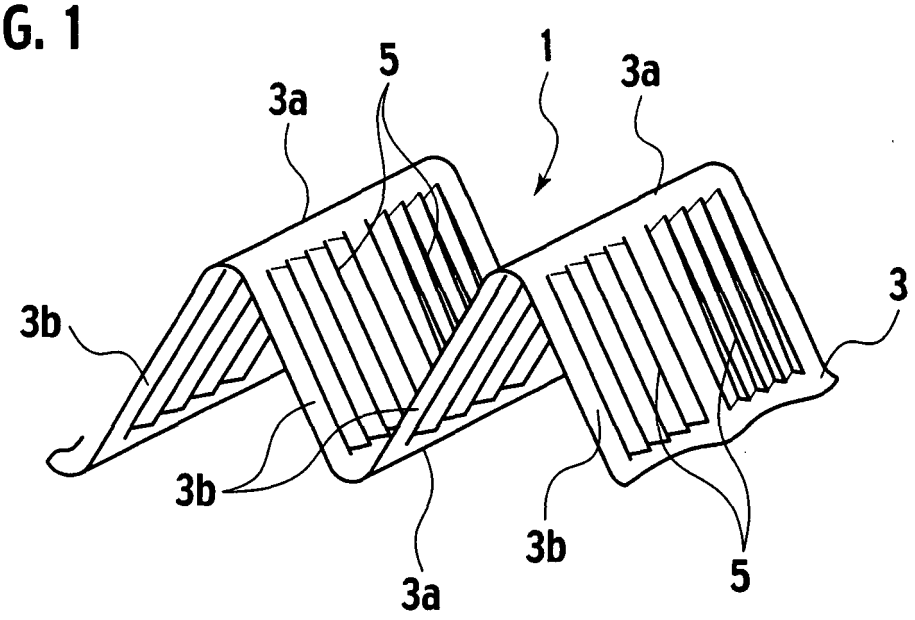



FIG. 2

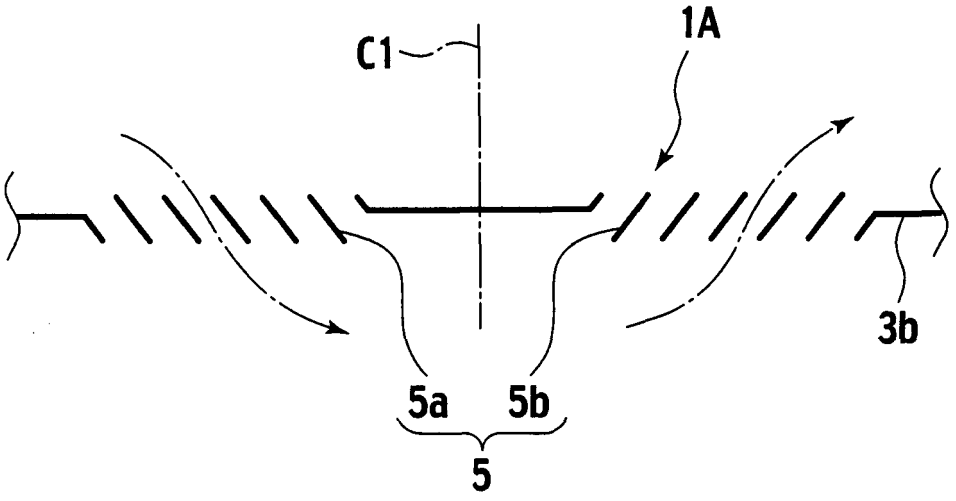


FIG. 3

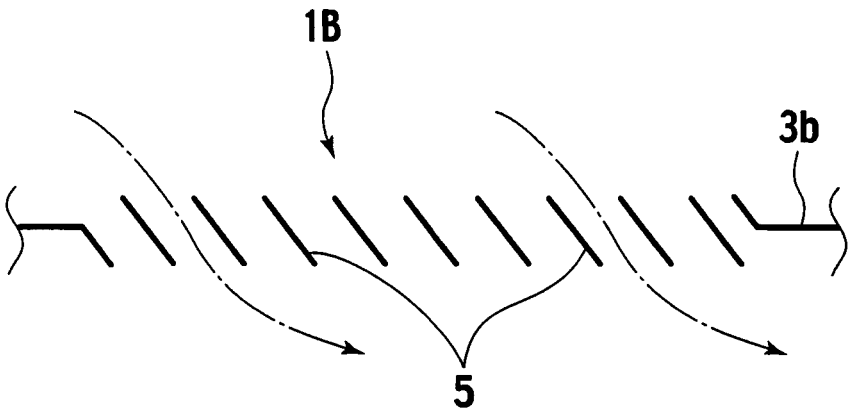



FIG. 4

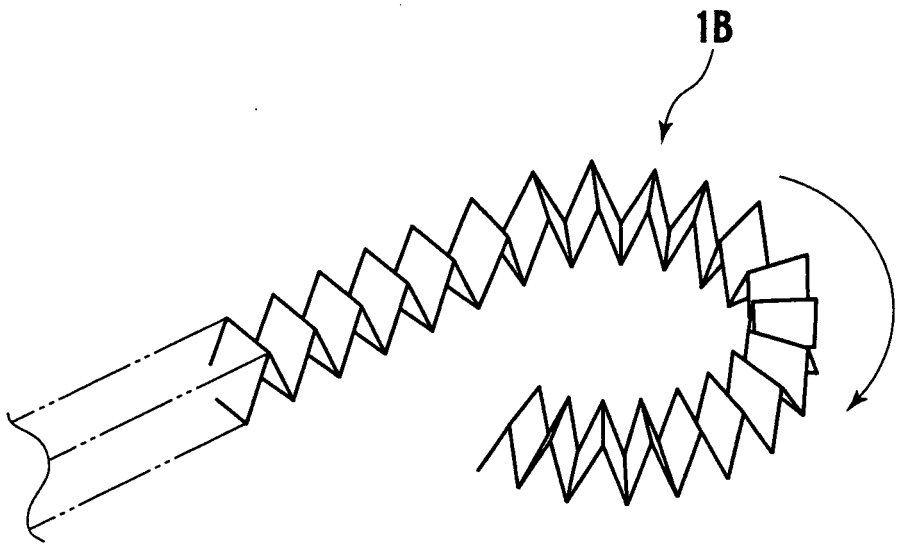


FIG. 5

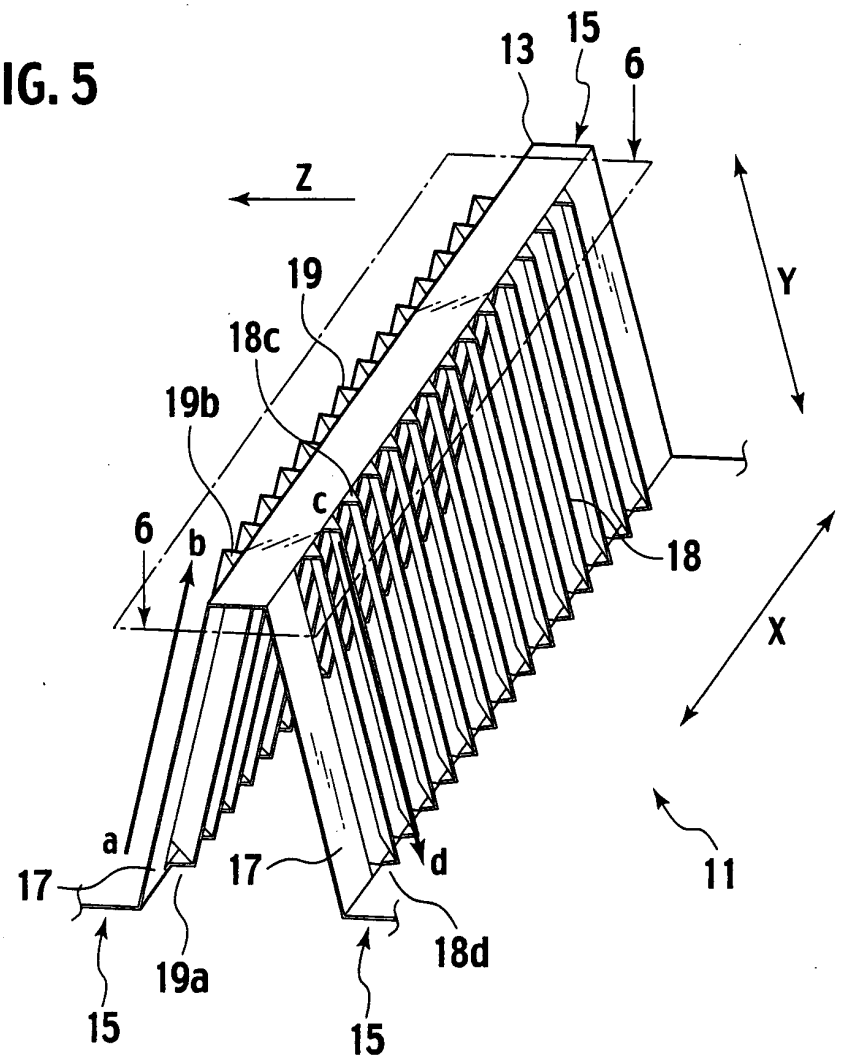



FIG. 6

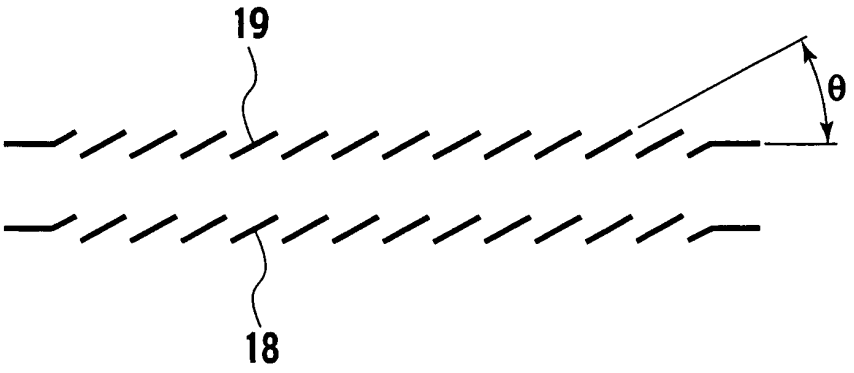


FIG. 7

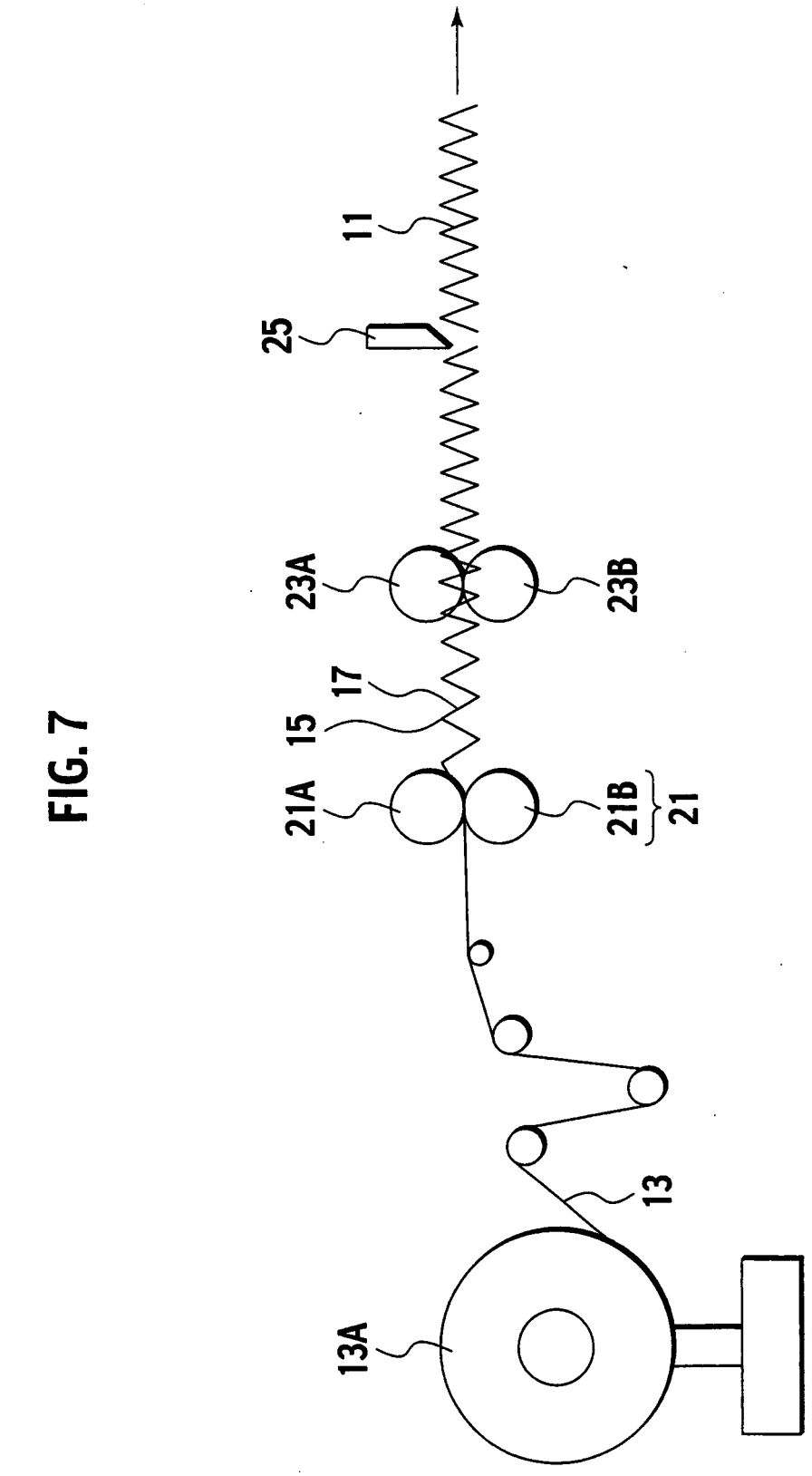


FIG. 8

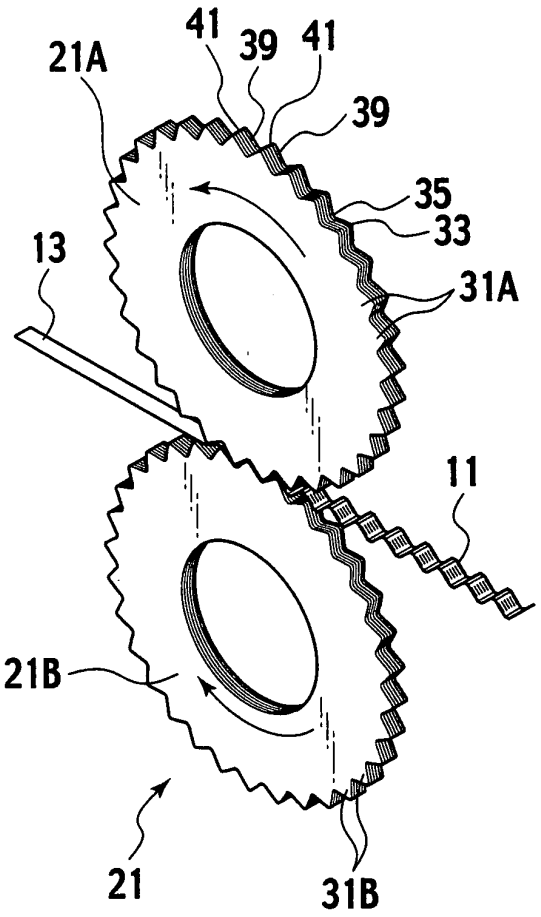



FIG. 9

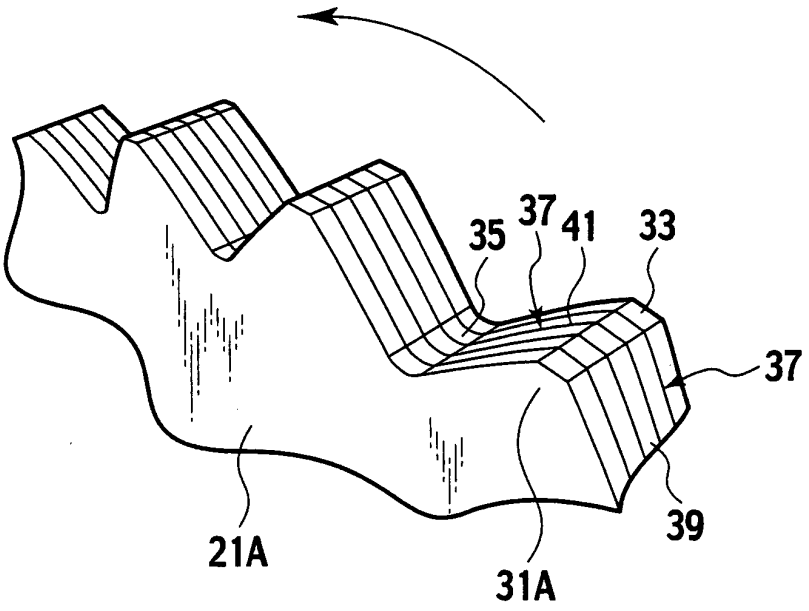


FIG. 10

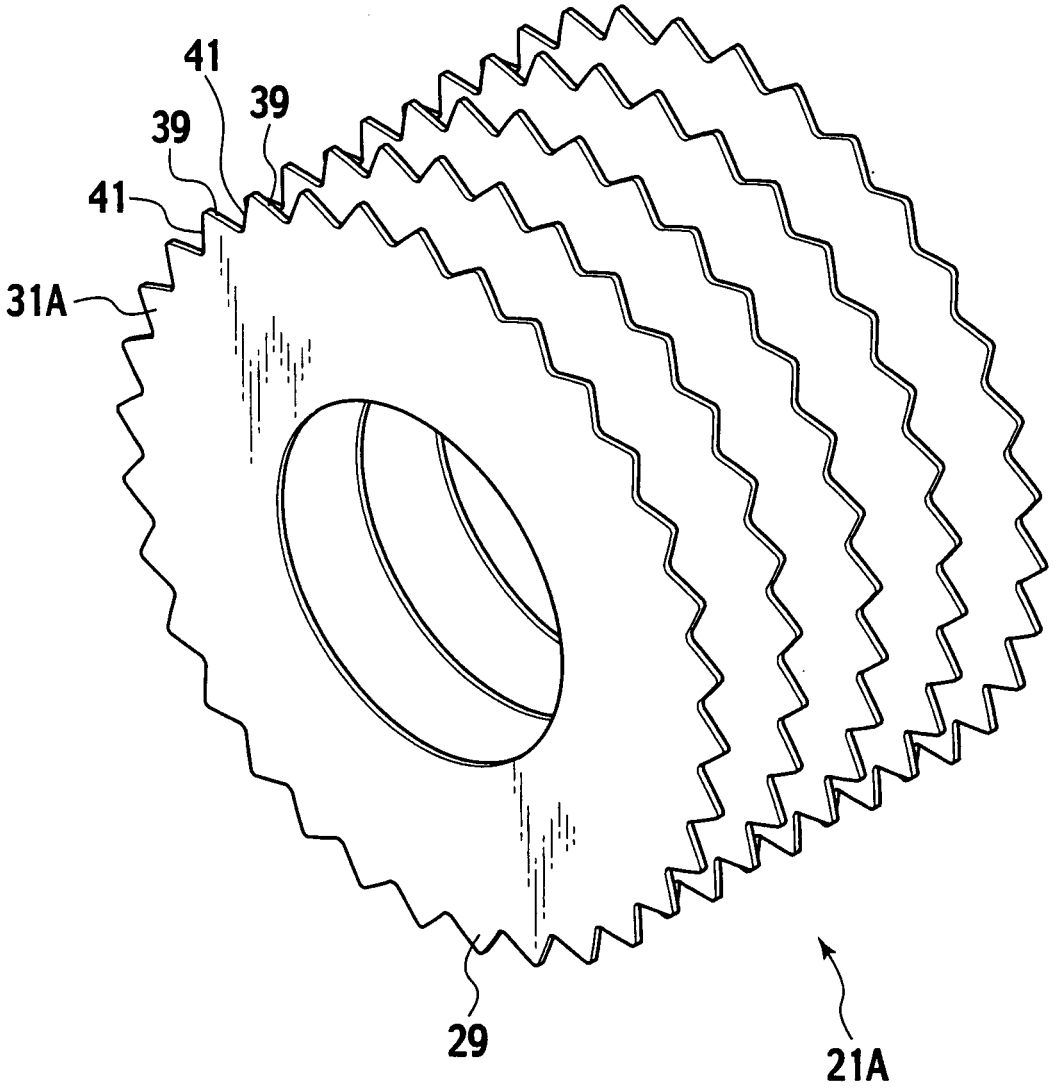


FIG. 11

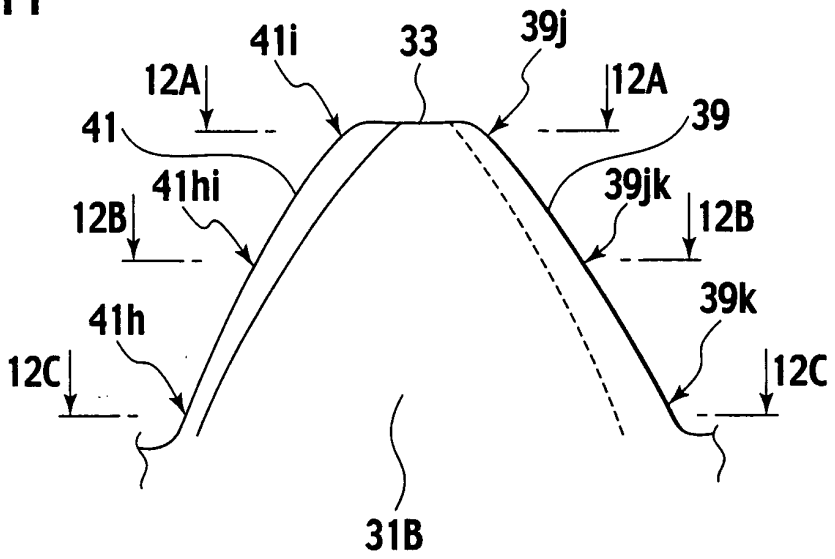

41i
33
39j
12A
12A
41
39
41hi
39jk
12B
12B
39k
41h
12C
12C
31B

FIG. 12

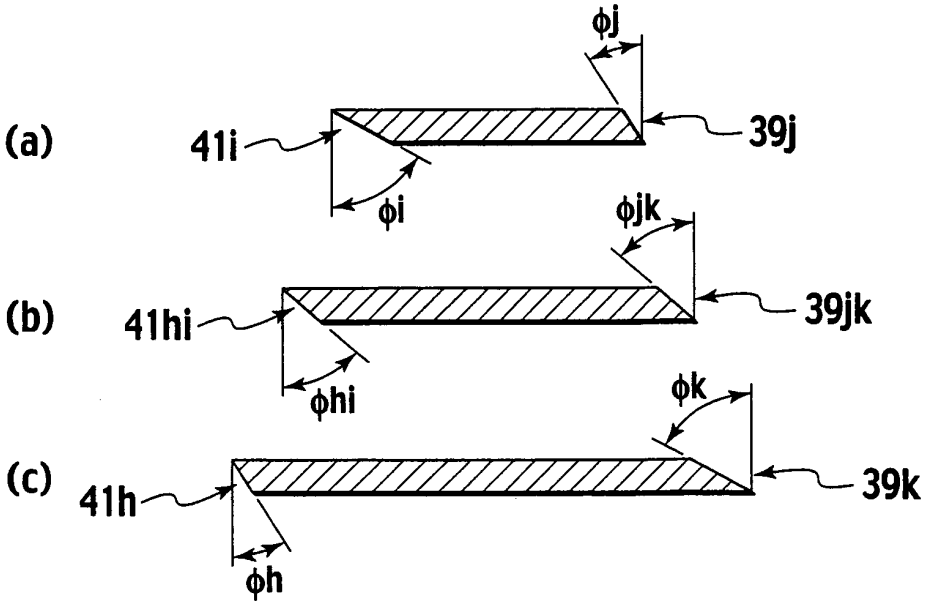

(a)
φj
41i
39j
φi
(b)
φjk
41hi
39jk
φhi
(c)
φk
41h
39k
φh

FIG. 13

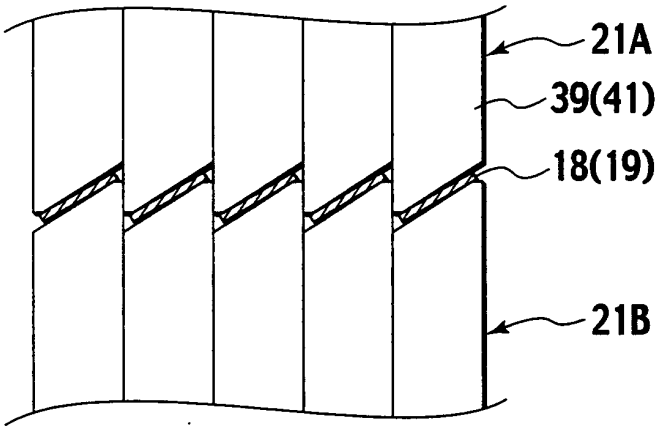

21A
39(41)
18(19)
21B

FIG. 14

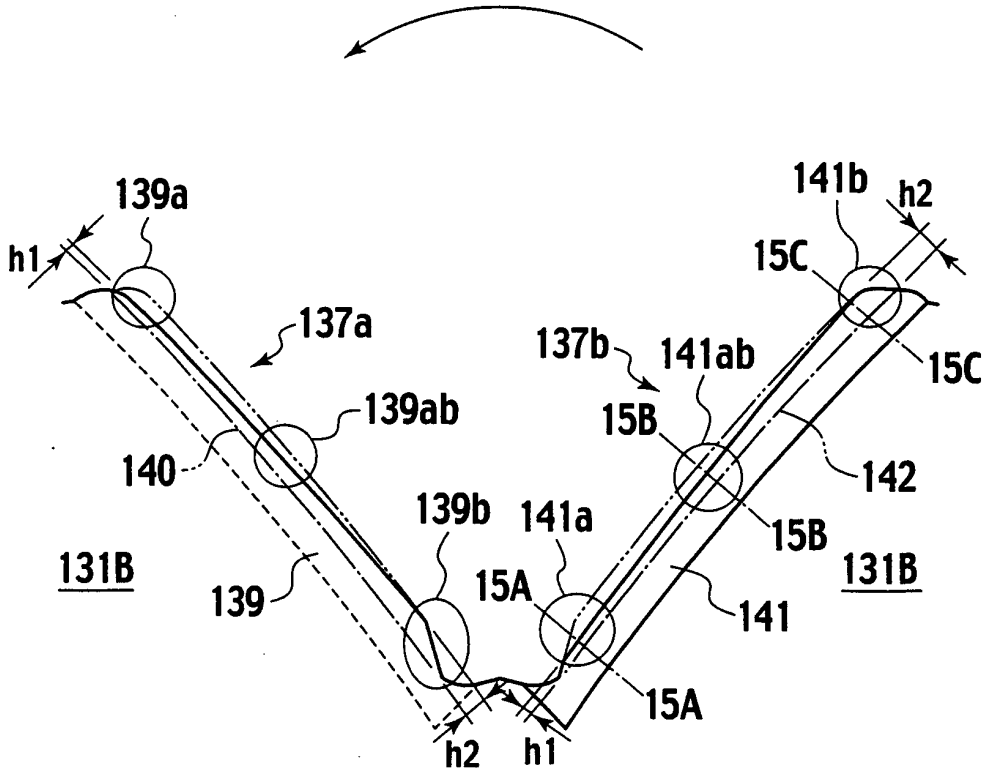
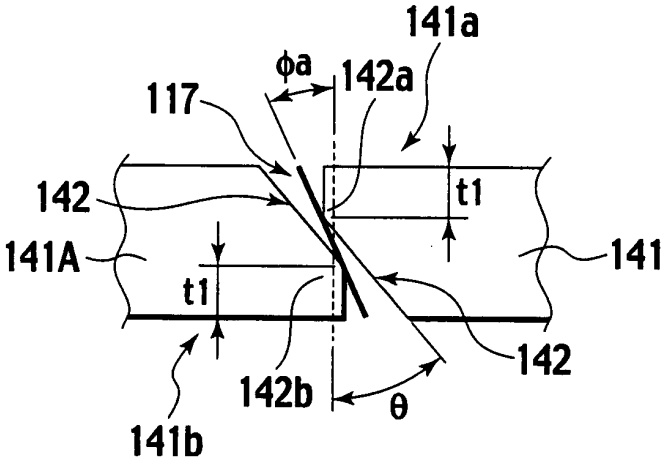
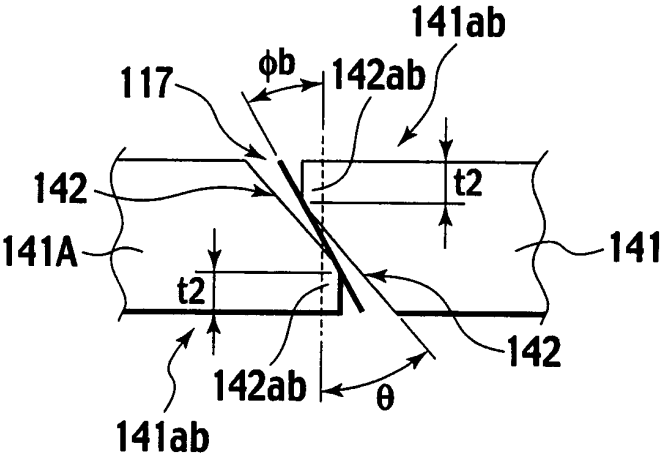

139a
h1
137a
139ab
140
131B
139
139b
141a
15A
h2
h1
141b
h2
15C
137b
141ab
15C
15B
142
15B
131B
141
15A

FIG. 15

(a)


141a
φa
142a
117
142
t1
141A
141
t1
142
142b
θ
141b

(b)


141ab
φb
142ab
117
142
t2
141A
141
t2
142
142ab
θ
141ab

(c)

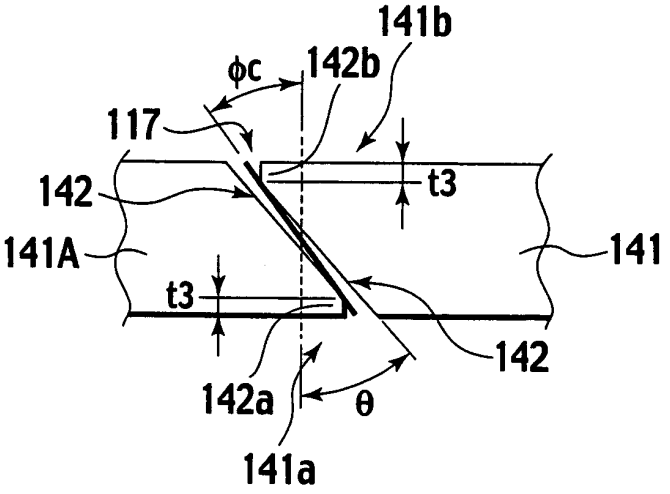

141b
φc
142b
117
142
t3
141A
141
t3
142
142a
θ
141a

FIG. 16

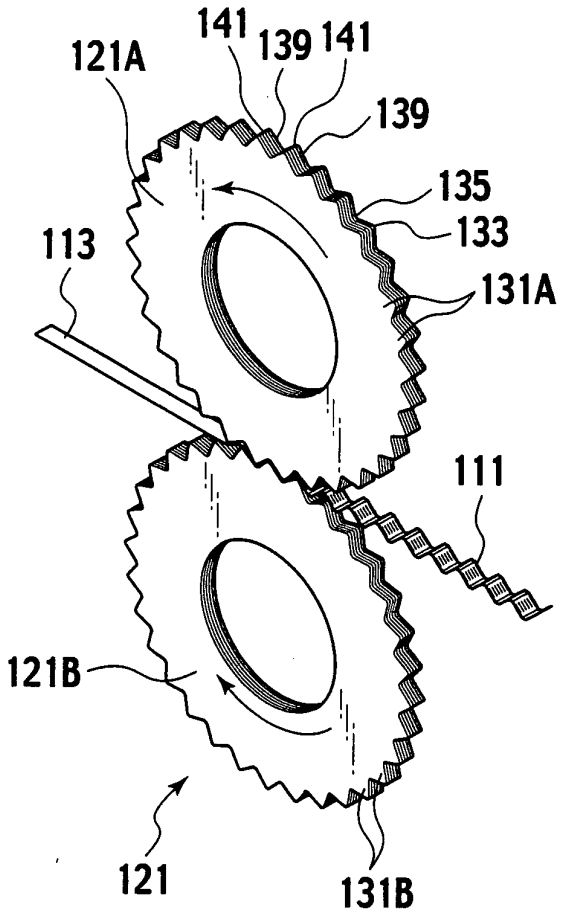

141
139
141
121A
139
135
133
113
131A
111
121B
121
131B

FIG. 17

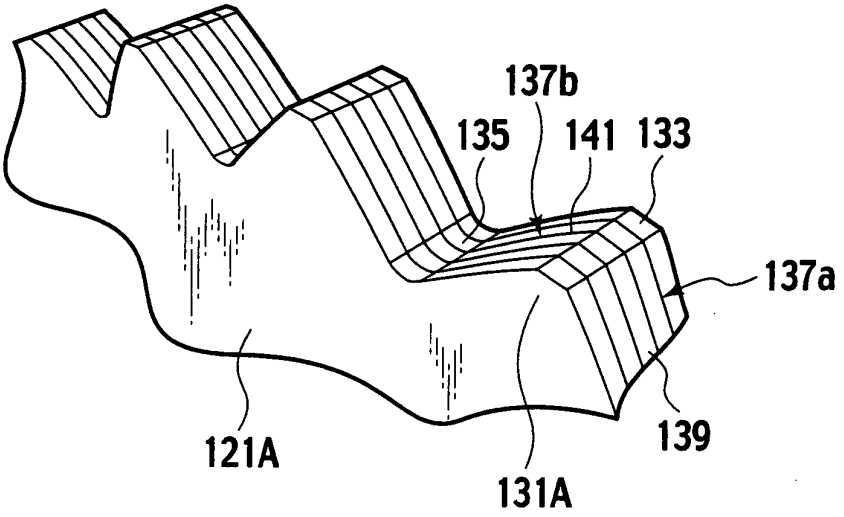

137b
135
141
133
137a
121A
139
131A

FIG. 18

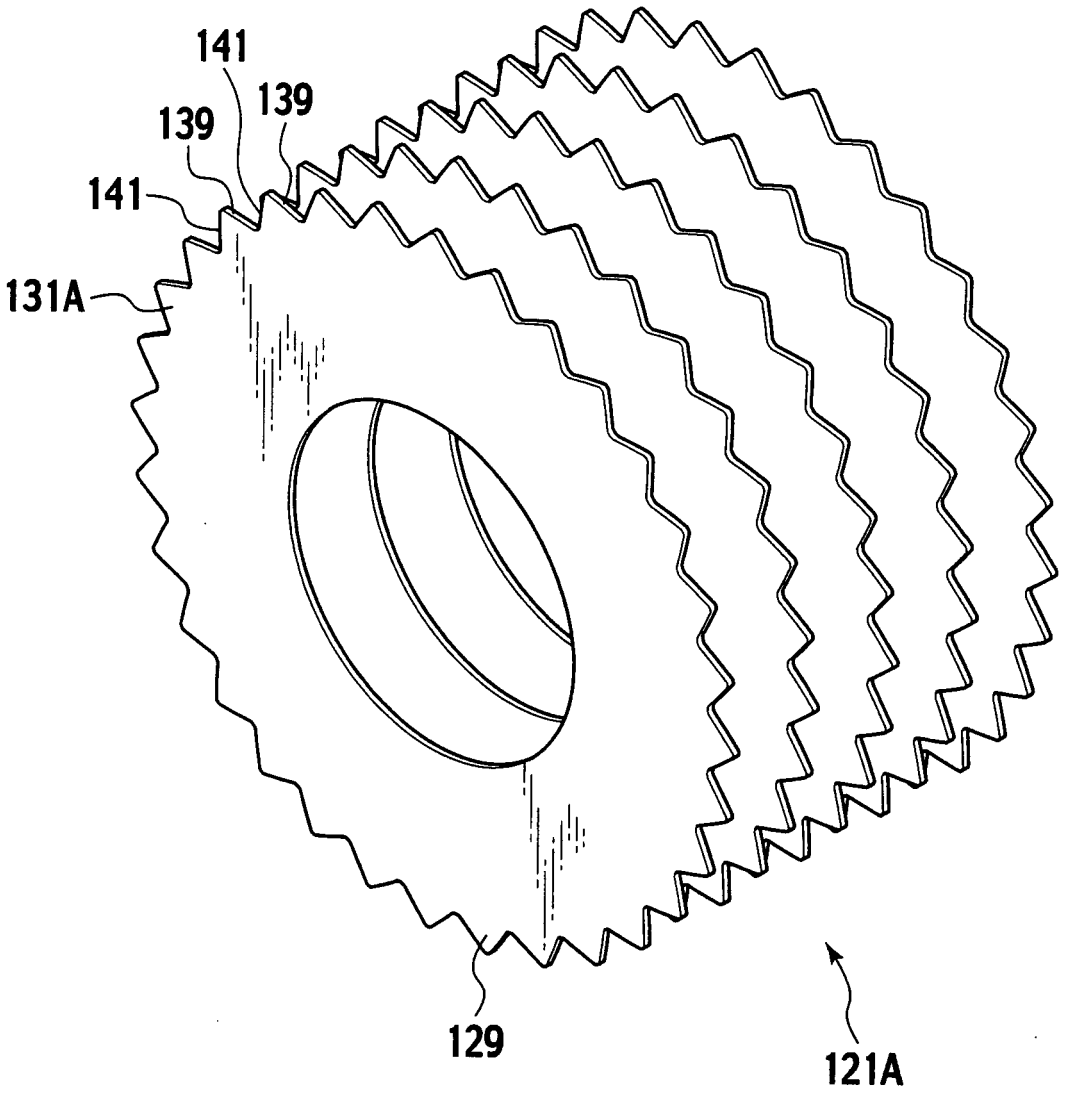


FIG. 19

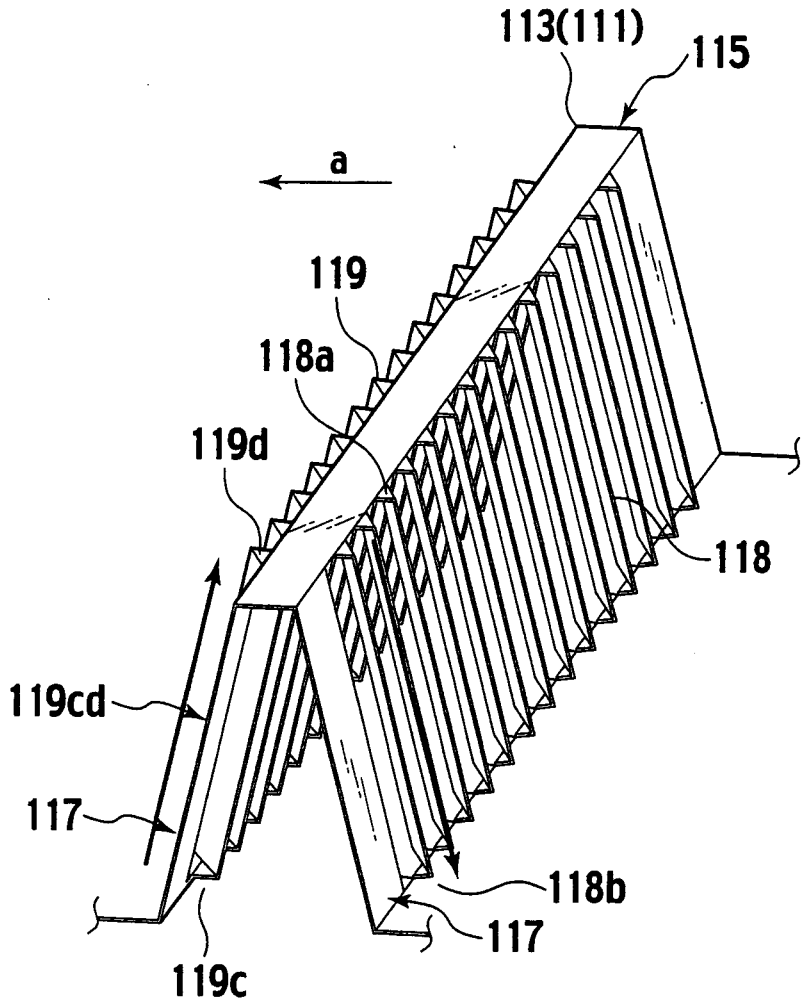


FIG. 20

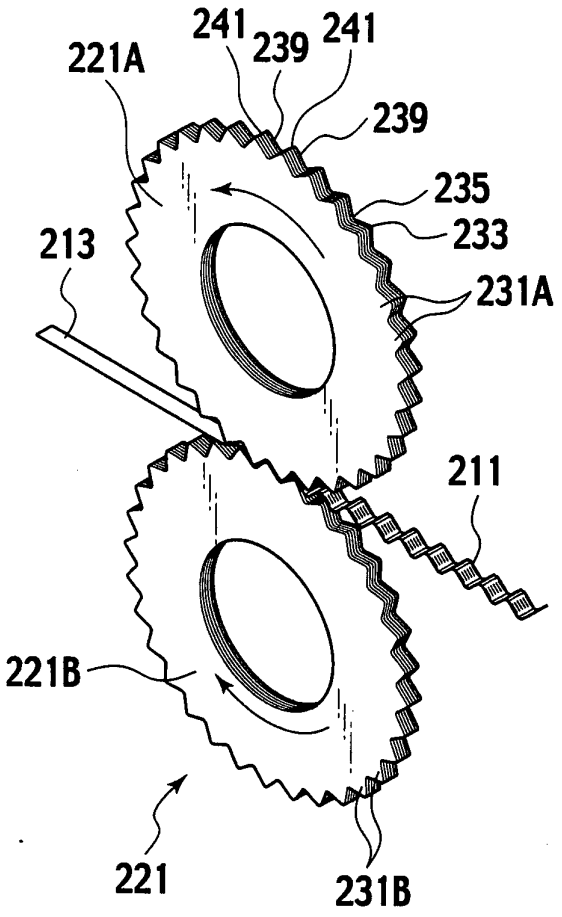

241
239
241
221A
239
235
233
213
231A
211
221B
221
231B

FIG. 21

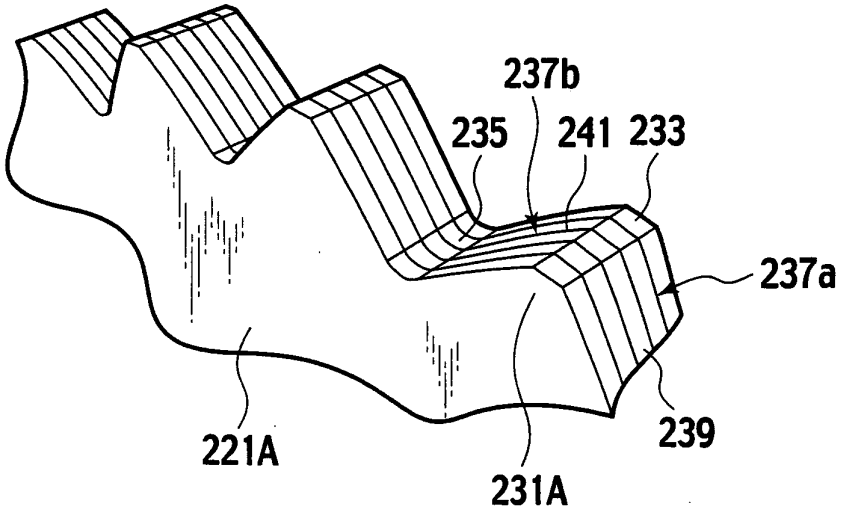

237b
235
241
233
237a
221A
231A
239

FIG. 22

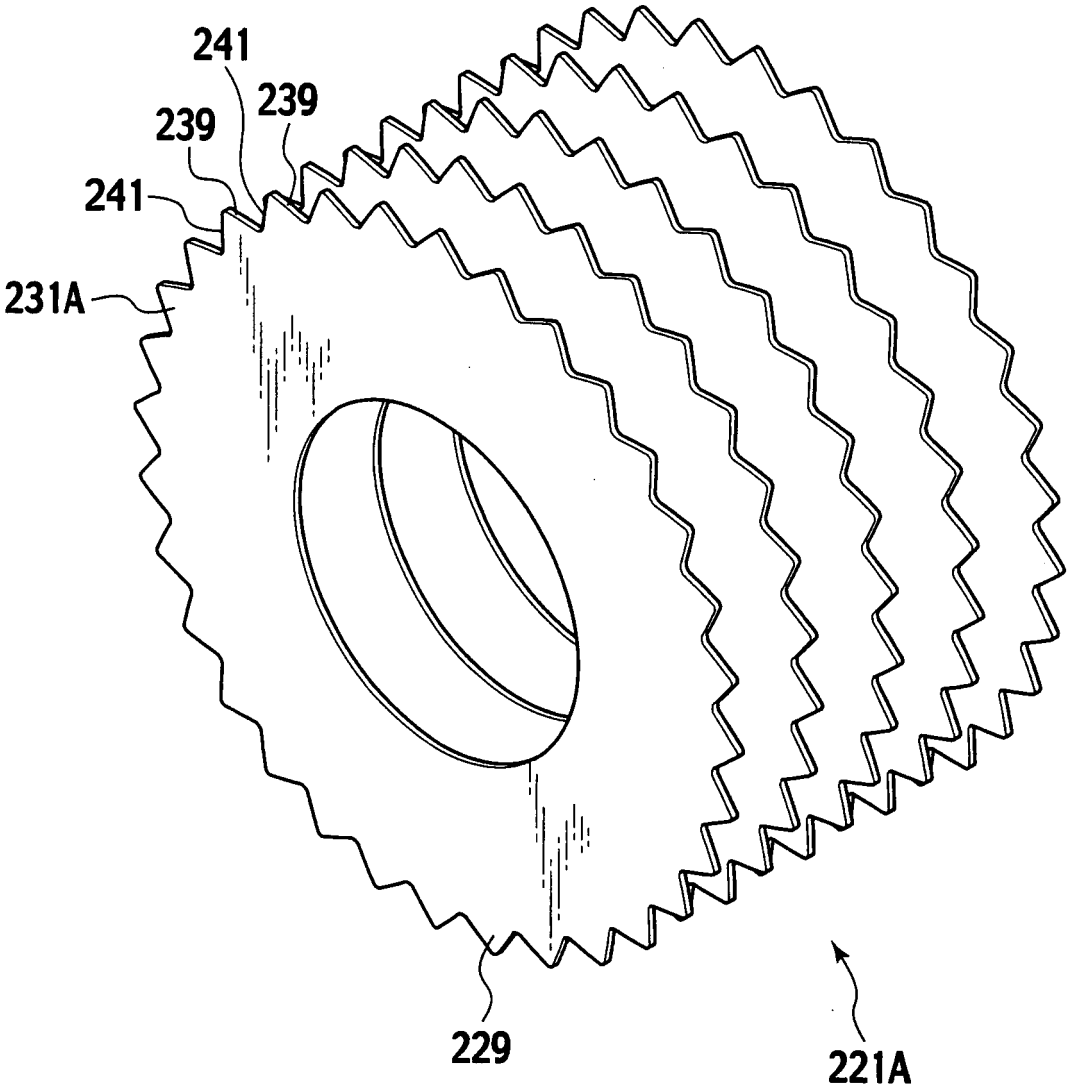


FIG. 23

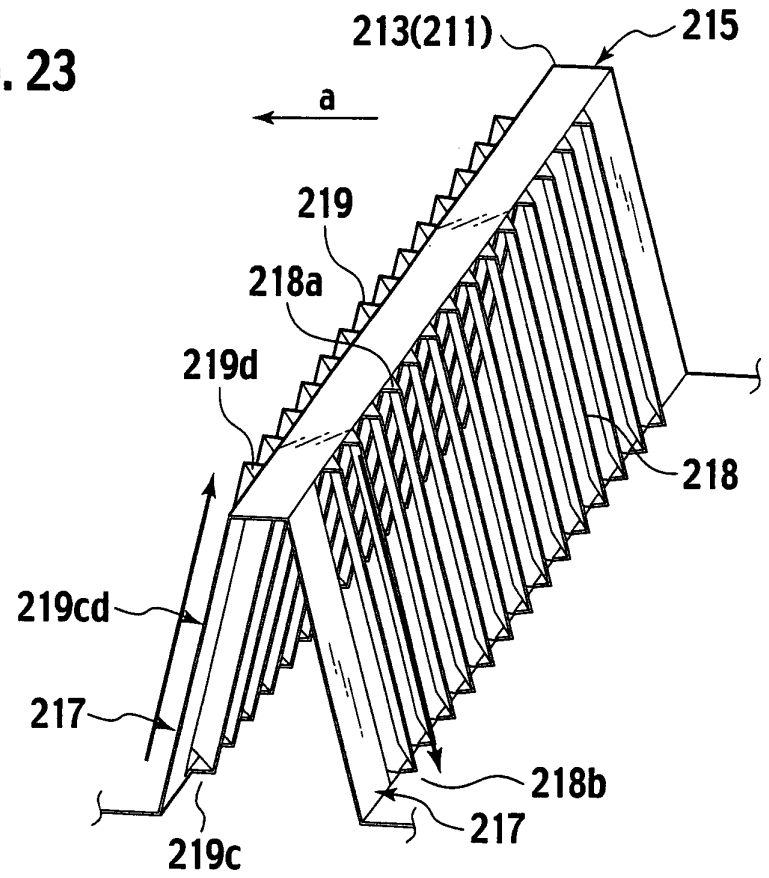

213(211)
215
a
219
218a
219d
218
219cd
217
218b
217
219c

FIG. 24

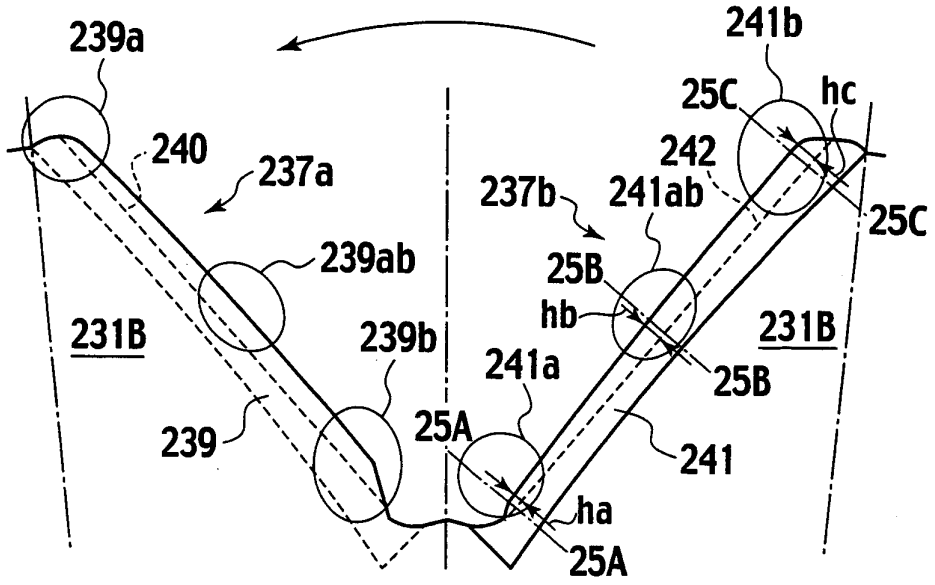
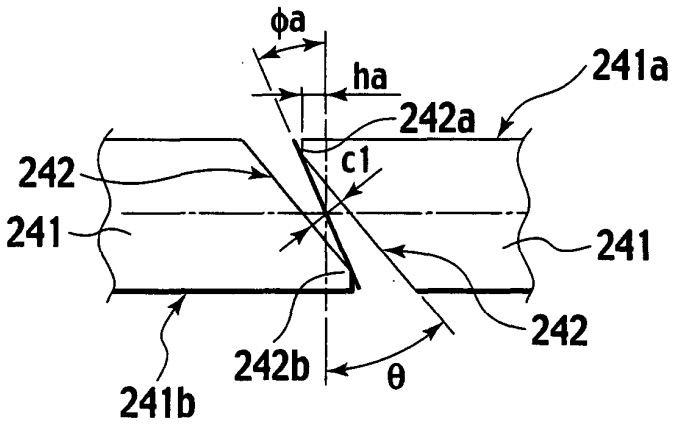
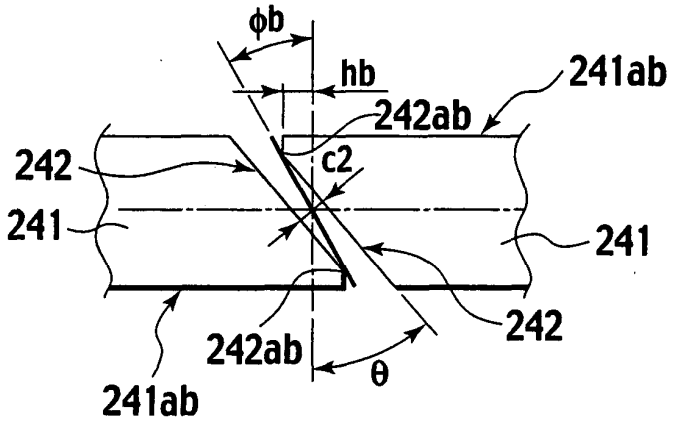

239a
241b
25C
hc
240
237a
242
237b
241ab
25C
239ab
25B
hb
231B
239b
231B
241a
25B
239
25A
241
ha
25A

FIG. 25

(a)


φa
ha
241a
242a
c1
242
241
241
242
242b
θ
241b

(b)


φb
hb
241ab
242ab
c2
242
241
241
242
242ab
θ
241ab

(c)

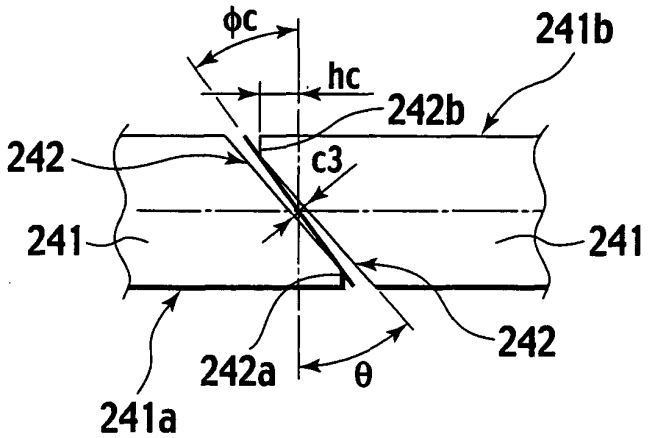

φc
hc
241b
242b
c3
242
241
241
242
242a
θ
241a

FIG. 26

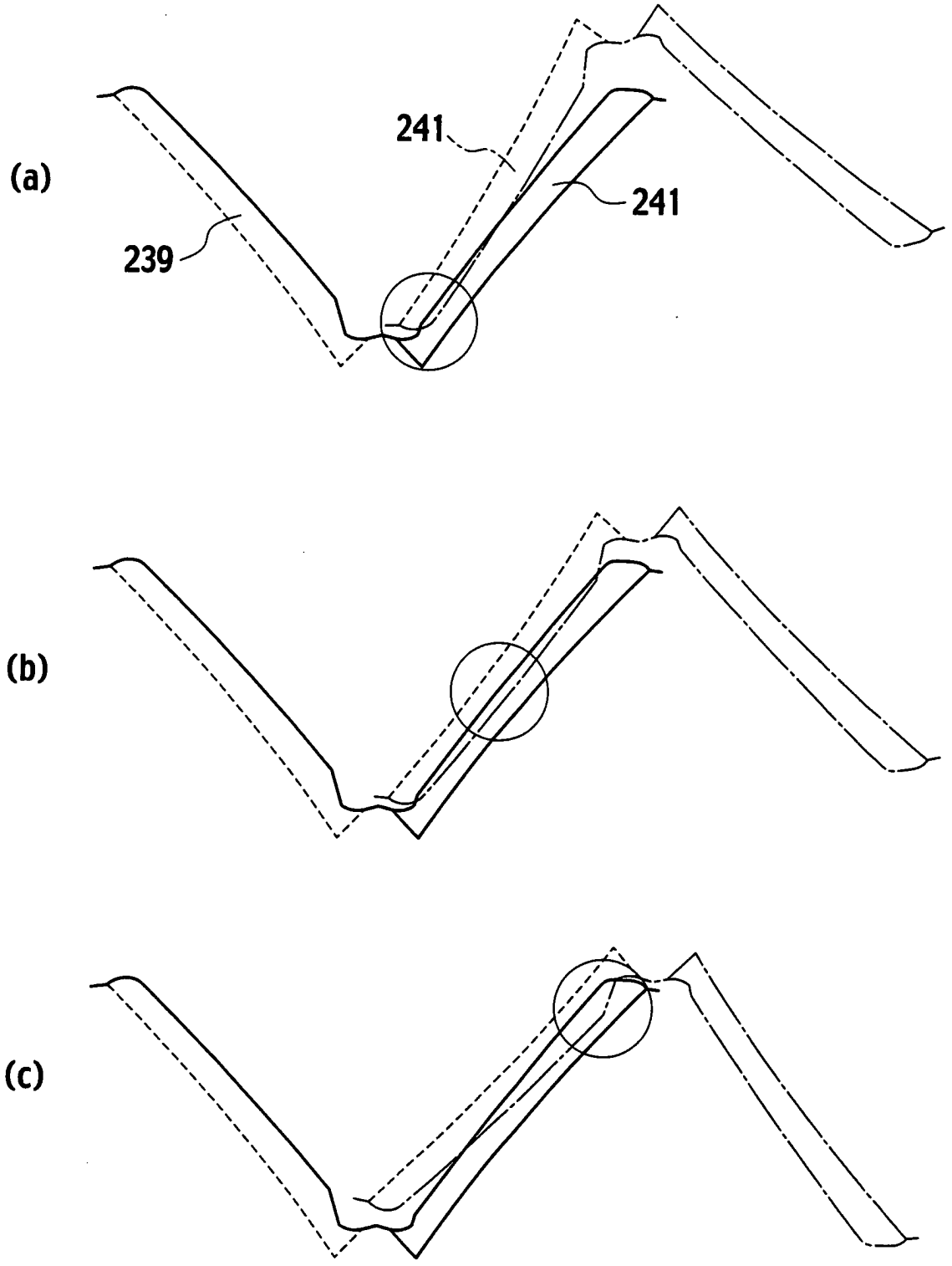
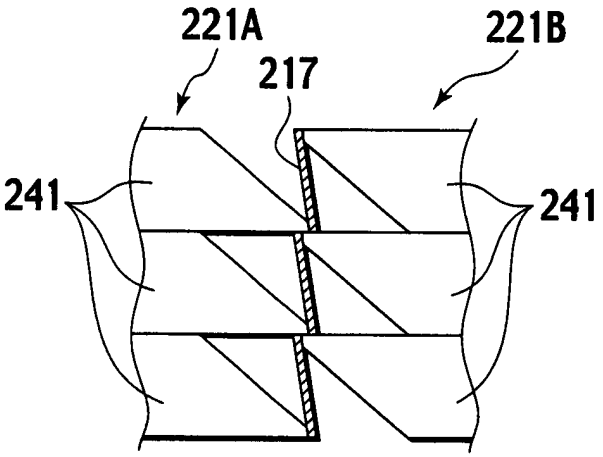
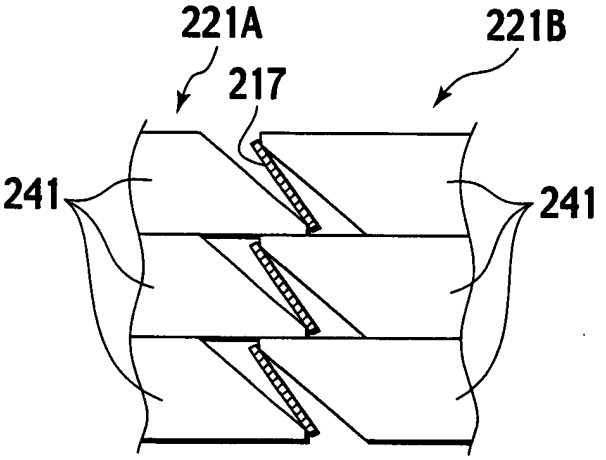


FIG. 27

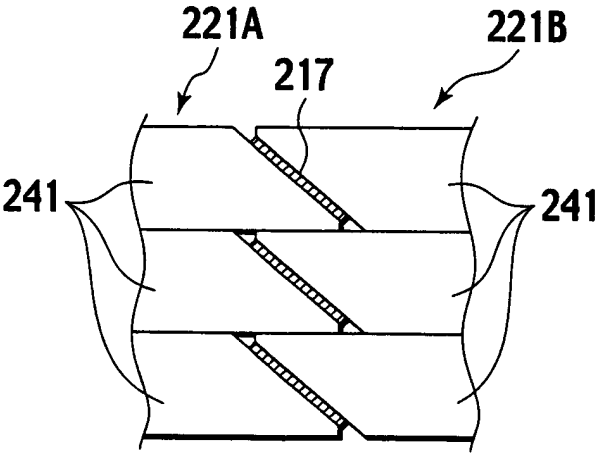
(a)


221A
221B
217
241
241

(b)


221A
221B
217
241
241

(c)


221A
221B
217
241
241

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2005/017455

A. CLASSIFICATION OF SUBJECT MATTER
***F28F1/30*** (2006.01), ***B21D13/04*** (2006.01), ***B21D28/10*** (2006.01), ***B21D28/12*** (2006.01), ***B21D53/08*** (2006.01), ***B23P13/00*** (2006.01)

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*** (2006.01), ***B21D13/04*** (2006.01), ***B21D28/10*** (2006.01), ***B21D28/12*** (2006.01), ***B21D53/08*** (2006.01), ***B23P13/00*** (2006.01)

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 1996-2005
Kokai Jitsuyo Shinan Koho 1971-2005 Toroku Jitsuyo Shinan Koho 1994-2005

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. |
|---|---|---|
| X | JP 2003-262484 A (Calsonic Kansei Corp.), 19 September, 2003 (19.09.03), Par. Nos. [0024] to [0029], [0032] to [0034]; Figs. 1 to 5 & EP 1455157 A2 | 1 |
| A | Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 009555/1980(Laid-open No. 112015/1981) (Nippon Radiator Kabushiki Kaisha), 29 August, 1981 (29.08.81), Full text; Figs. 1 to 7 (Family: none) | 2-6 |

☒ 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 another 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 |
|---|---|
| 06 December, 2005 (06.12.05) | 20 December, 2005 (20.12.05) |
| Name and mailing address of the ISA/ Japanese Patent Office<br>Facsimile No. | Authorized officer<br>Telephone No. |

Form PCT/ISA/210 (second sheet) (April 2005)

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2005/017455

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 165038/1983(Laid-open No. 074807/1985) (Nippon Radiator Kabushiki Kaisha), 25 May, 1985 (25.05.85), Full text; Figs. 5, 6, 8 (Family: none) | 2-6 |

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

## REFERENCES CITED IN THE DESCRIPTION

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

### Patent documents cited in the description


- JP 2003083691 A **[0007]**
- JP 1002833 A **[0035] [0035] [0062]**