(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 May 2013 (10.05.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/063754 A1

(51) International Patent Classification:
F01N 3/28 (2006.01) *B01J 35/04* (2006.01)

(21) International Application Number:
PCT/CN2011/081618

(22) International Filing Date:
1 November 2011 (01.11.2011)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **BASF CORPORATION** [US/US]; 100 Campus Drive, Florham Park, New Jersey 07932 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **CHU, Gengsheng** [CN/CN]; 18 Can Luan Road, Hi-Tech&Industry Developing Zone, Guilin, Guangxi 541004 (CN). **DENG, Shuiping** [CN/CN]; 18 Can Luan Road, Hi-Tech&Industry Developing Zone, Guilin, Guangxi 541004 (CN). **ZHANG, Yuqin** [CN/CN]; 18 Can Luan Road, Hi-Tech&Industry Developing Zone, Guilin, Guangxi 541004 (CN). **LIU, Ye** [US/US]; 25 Middlesex-Essex Turnpike, Iselin, New Jersey 08830 (US). **TAO, Weichang** [CN/CN]; 18 Can Luan Road, Hi-Tech&Industry Developing Zone, Guilin, Guangxi 541004 (CN). **BARTHOLOMAEUS, Peter** [DE/CN]; 239 Luqiao Road, Pudong, Shanghai 201206 (CN).

(74) Agent: **ZHONGZI LAW OFFICE**; 7F, New Era Building, 26 Pinganli Xidajie, Xicheng District, Beijing 100034 (CN).

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

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

Published:

— *with international search report (Art. 21(3))*

(54) **Title**: SYSTEM AND METHOD FOR MANUFACTURING A HONEYCOMB BODY

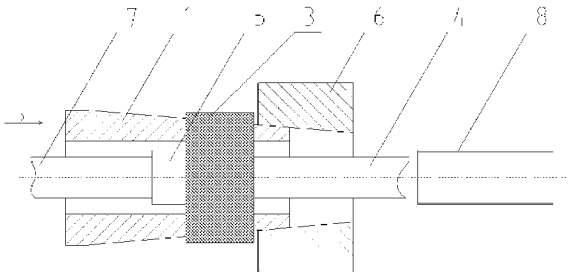

FIG. 2

(57) **Abstract**: A system and method for manufacturing a honeycomb body is provided. Said system comprising: a forming mold (1) with a plurality of sub-molds, which are movable so that they can be opened and closed; a tightening mold (6) for tightening said forming mold (1); rolling pin(s) (2), which can be inserted into and pulled out of the inner volume of said forming mold (1) and can rotate around a rotation axis; wherein said tightening mold (6) has a shape that cooperates with the shape of said forming mold (1), so that an action of said tightening mold (6) causes tightening of said forming mold (1).

WO 2013/063754 A1

SYSTEM AND METHOD FOR MANUFACTURING A HONEYCOMB BODY

Technical field

The present invention relates to a system and a method for manufacturing a honeycomb body, more specifically, to system and method for manufacturing an S-type metal honeycomb body.

Background

Honeycomb bodies are commonly used in many fields, such as filters, catalyst substrates in the engine exhaust purification system. Honeycomb body has large channel surface area, low back pressure, excellent mechanical performance and catalysis engineering speciality. In recent years, S-type metal honeycomb body is of particular concern.

Metal honeycomb body is usually made of metal foil. The honeycomb structure needs to be continuously tightened so as to define the internal channels of the honeycomb structure. The precision of the honeycomb body manufacturing will affect its life and other properties.

Device and method for manufacturing a honeycomb body is known form the state of art. For example, WO97/10135 describes a device and a method for manufacturing a honeycomb body. The device includes a fork rolling mechanism, which rotates around an axis and holds the foil stack, and an arc mold segment, which can close to form a mold. The model consists of at least two mold segments, which can rotate around their axes respectively. The axes of rotation are parallel with the rolling axis respectively. In CN 101251036A also a device and a method for manufacturing a honeycomb body are known. The device includes a fixed post and two sets of mold segments, which can be closed to form a mold. These devices are not only complex, difficult to manufacture, and also lack of accuracy.

US 7, 318, 276B2 discloses a method for finish machining a honeycomb body, wherein the honeycomb structure are processed by means of fine-processing tools after being rolled, so as to meet the required performance.

Some of the technical solutions in the art either lead to inadequate performance of honeycomb body and even waste products due the inaccuracy of the honeycomb body's shape. Other solutions, in spite of enhancing the manufacturing precision, cause high complexity in configuration, difficulty in accurate control, and/or high costs in the manufacturing process.

Summary of the invention

The invention is based on the purpose to provide a system for automatically manufacturing a honeycomb body; the system has simple structure and can produce honeycomb bodies with good stability and long life.

According to the invention, the system includes a forming mold with a plurality of sub-molds, which are movable so that they can be opened and closed; a tightening mold for tightening said forming mold, i.e. for closing the sub-molds thereof; rolling pin(s), which can be inserted into and pulled out of the inner volume of said forming mold and can rotate around a rotation axis. According to this invention, said tightening mold has a shape that cooperates with the shape of said forming mold, so that an action of said tightening mold causes tightening of said forming mold.

By means of this system, the honeycomb structure can be manufactured with high accuracy without using complex tightening system, such as those in the prior art.

According to a preferred embodiment, said forming mold has a conical outer surface, which cooperates with a conical inner surface of said tightening mold, and said tightening mold are displaced in the axial direction in the action. This solution is preferred

since the tightening mold can be easily and precisely controlled. Thus, not only the tightening mold itself, but also the driving train thereof, can be simply constructed and manufactured with low cost. This tightening mold can be easily driven, for example, by an electric motor via a gear-rack transmission, worm transmission and the like.

Other solutions are also possible for providing the forming mold and the tightening mold with cooperating configurations, such as mating structures with thread or groove and the like.

The forming mold preferably comprises four sub-molds. But a forming mold with only two, six or more sub-molds is also conceivable, that leads to a simpler solution. More sub-molds bring more evenly distributed acting force to the honeycomb body, but also brings more complexity to the structure.

Preferably, the sub-molds can be closed to form a cylindrical, circumferential closed inner volume. This solution brings the advantage, that the final size of the honeycomb structure is controlled precisely merely by the geometry characters of the sub-molds. Thus a manufacturing system with high accuracy can be provided easily.

According to a preferred embodiment, the manufacturing system further comprises an ejecting part, which is movable in the axial direction so as to push the rolled-up honeycomb structure into a housing. Thus a highly automated system is achieved.

Also for the purpose of providing a highly automated system, a automatic feeding device for feeding said forming mold with foil stack to be rolled is provided.

A method for manufacturing honeycomb body by using the above described system is also suggested. The method comprises the following steps:

opening the forming mold;

introducing the foil stack into the space between the rolling pins;

rotating the rolling pins until the foil stack is fully rolled into the forming mold;

rotating the rolling pins while activating the tightening mold, with the action thereof causing the inner volume of the forming mold decreasing to a first value;

pulling the rolling pins out of the structure formed by the foil stack;

pushing the rolled-up honeycomb structure into a housing by means of the ejecting part.

By means of this method, honeycomb bodies can be automatically produced with high accuracy. The produced honeycomb bodies have gut behavior and long life, because of this precisely controlled process, in which the honeycomb structure is tightened while being rolled up.

Preferably, a further step is provided between the step of pulling the rolling pins out and the step of pushing the rolled-up honeycomb structure into a housing, in which the tightening mold further functions so as to cause the inner volume of the forming mold decreasing to a second value.

Brief Description of the Drawings

Figure 1 is a schematic drawing of the system according to the invention;

Figure 2 is a section of the manufacturing system, with the system in a state when the foil stack is being introduced;

Figure 3 is a drawing of the system according to the invention looking from the arrow D in Figure 2;

Figure 4 is a drawing corresponding to Figure 2, with the foil stack being already rolled and the tightening mold being already crossed a distance;

Figure 5 is a drawing corresponding to Figure 3, with the foil stack being already rolled and the tightening mold being already crossed a distance;

Figure 6 is a block diagram showing the process for manufacturing a honeycomb body.

Detailed Description

Figure 1 shows a system for manufacturing a honeycomb according to the invention. The system includes a frame, driving trains, a forming mold 1 for rolling volume of the honeycomb-type and tightening mold 6.

Figure 2 and 3 show a section of the system for manufacturing a honeycomb according to the invention. The forming mold 1 consists of four sub-molds independent of each other (see Figure 3), which four sub-molds can be opened and closed. For example, the four sub-molds are supported on the frame like the jaws of a four-jaw chuck. The sub-molds are preferably movable in the radial direction in their own slide rails respectively. The sub-molds are biased to the direction of opening by springs. The four sub-molds can naturally be arranged in other known means.

As can be seen from Figure 3, there are gaps between the four sub-molds A in their opening state, through which gap a foil stack 3 to be rolled can be introduced into the forming mold 1. The foil stack 3 is produced by stacking wave metal foils and flat metal foils alternatively.

In the present embodiment, the four sub-molds of the forming mold 1 are hold in a tightening mold 6. The forming mold 1 includes a conical outer surface, which engages with a conical inner surface of the tightening mold 6 in such a way, that the he forming mold 1 are contracted continuously by the axial movement (shown by arrow D) of the tightening mold 6. That result in the tightening of the honeycomb lying in the forming mold 1, see Figure 4 and Figure 5. In one embodiment, the four sub-molds can be contracted to form a close cylindrical cavity.

The forming mold 1 and the tightening mold 6 engage with each other preferably by matched conical surfaces thereof. But engagements with other matched shapes can also be envisaged.

The system shown in Figure 1 includes rolling pins 2, which can be inserted into the inner volume of the forming mold 1. In the shown embodiment, two rolling pins 2 are provided so as to manufacture a double S-shaped honeycomb structure. Other conventional arrangements of the rolling pins for manufacturing corresponding honeycomb structure are also possible.

One end of the rolling pin 2 is supported in a pin driving shaft 7. The pin driving shaft 7 can rotate around its longitudinal axis. The rolling pins are driven by the pin driving shaft 7 in such a way, that they rotate around an axis X, which is parallel to both of the rolling pins 2. The axis X of the rolling pins locates in the center of the forming mold 1 and is equally distanced from the rolling pins 2. The foil stack 3 is rolled up by the rotation of the rolling pins 2 and form an S-shaped honeycomb structure. The pin driving shaft 7 can by moved axially to a first position, in which the rolling pins 2 are inserted into the volume of the forming mold 1, and a second position, in which the rolling pins 2 are pulled out of the volume.

The system 10 also includes an ejecting part 5, which can slide on the pin driving shaft 7 so as to push the rolled honeycomb structure into an housing 8. Thus, a honeycomb is manufactured. In Figure 5, the central part of the foil stack 3, which has been rolled as a honeycomb structure, is coved by the ejecting part 5.

In one embodiment, a supporting shaft 4 for supporting the rolling pins 2 is provided on the other side of the rolling pins 2. The housing 8 is pushed on the supporting shaft 4. The supporting shaft 4 is axially movable, such that it can leave the housing 8

when the honeycomb structure is pushed out by the ejecting part 5.

The mechanics of the manufacturing system, i.e. the manufacturing method is described below:

First, the foil stack 3 is prepared. Usually a foil stack 3 is formed by simply stacking a certain number of wave foils and flat foils. Then a housing 8 for honeycomb is placed into the manufacturing system. For metal honeycomb bomolds, the housing is usually a steel sleeve.

In step S01, the forming mold 1 is opened.

In step S02, a foil stack 3 is introduced into the space between the two rolling pins 2 through the gap between two sub-molds, see Figure 2 and Figure 3.

In step S03, the rolling pin driving shaft 7 is rotated by the driving train. The rolling pins 2 are rotated by the rolling pin driving shaft 7 as such, that the foil stack 3 is rolled into the forming mold 1.

In a step S04, the tightening mold 6 is moved axially, so that the inner volume of the forming mold 1 gradually decreases to a first value, after the foil stack 3 is completely rolled into the forming mold 1. In the mean time, the rolling pins 2 keep rotating. In this embodiment, the tightening mold 6 moves linearly in a direction D in its tightening action. Due to the engagement of the conical inner surface of the tightening mold 6 with the conical outer surface of the forming mold 1, the sub-molds of the forming mold 1 are displaced inwardly in radial direction by the axial movement of the tightening mold 6, tightening the honeycomb structure formed by the foil stack 3, see Figure 4 and Figure 5.

In a step S05, the rolling pins 2 is pulled out after S04, and the tightening mold 6 is further moved, so that the inner volume of the forming mold 1 further decreases to a second value.

In a step S06, after the second value is reached, the ejecting part 5 pushes the rolled-up honeycomb

structure into a housing, so that a honeycomb with a housing and a rolled-up honeycomb structure is formed. In particular, the second value corresponds to the inner size of the forming mold 1 with the four sub-molds fully closed.

List of symbols

1	forming mold
2	rolling pins
3	foil stack
4	rolling pin driving shaft
5	ejecting part
6	tightening mold
7	supporting shaft
8	housing

Patent Claims

1. A system for manufacturing a honeycomb body, comprising:

a forming mold (1) with a plurality of sub-molds, which are movable so that they can be opened and closed;

a tightening mold (6) for tightening said forming mold (1);

rolling pin(s) (2), which can be inserted into and pulled out of the inner volume of said forming mold (1) and can rotate around a rotation axis;

characterized in that,

said tightening mold (6) has a shape that cooperates with the shape of said forming mold (1), so that an action of said tightening mold (6) causes tightening of said forming mold (1).

2. The system of claim 1, characterized in that, said tightening mold (6) has a conical inner surface, which cooperates with a conical outer surface of said forming mold (1), and said tightening mold (6) are displaceable in the axial direction.

3. The system of claim 1 or 2, characterized in that, said forming mold (1) comprises four sub-molds.

4. The system of claim 1 or 2, characterized in that, said sub-molds can be closed to form a cylindrical, circumferential closed inner volume.

5. The system of claim 1 or 2, characterized in that, further comprising an ejecting part (5), which is movable in the axial direction so as to push the rolled-up honeycomb structure into a housing (8).

6. The system of claim 1 or 2, characterized in that, further comprising a rolling pin driving shaft (7), which supports one end of the rolling pin (2), and on

which said ejecting part (5) is arranged, such that said ejecting part (5) is slidable on the rolling pin driving shaft (7).

7. The system of claim 1 or 2, characterized in that, further comprising a automatic feeding device for feeding said forming mold (1) with foil stack (3) to be rolled.

8. A method for manufacturing honeycomb body, wherein the system of one of the above claims is applied, the method comprising the following steps:

opening the forming mold (S01);

introducing the foil stack into the space between the rolling pins(S02);

rotating the rolling pins until the foil stack is fully rolled into the forming mold (S03);

rotating the rolling pins while activating the tightening mold, with the action thereof causing the inner volume of the forming mold decreasing to a first value (S04);

pulling the rolling pins out of the structure formed by the foil stack (S05);

pushing the rolled-up honeycomb structure into a housing by means of the ejecting part (S07).

9. A method of claim 8, characterized in that, a further step is provided between the step of pulling the rolling pins out and the step of pushing the rolled-up honeycomb structure into a housing, in which the tightening mold further functions so as to cause the inner volume of the forming mold decreasing to a second value (S06).

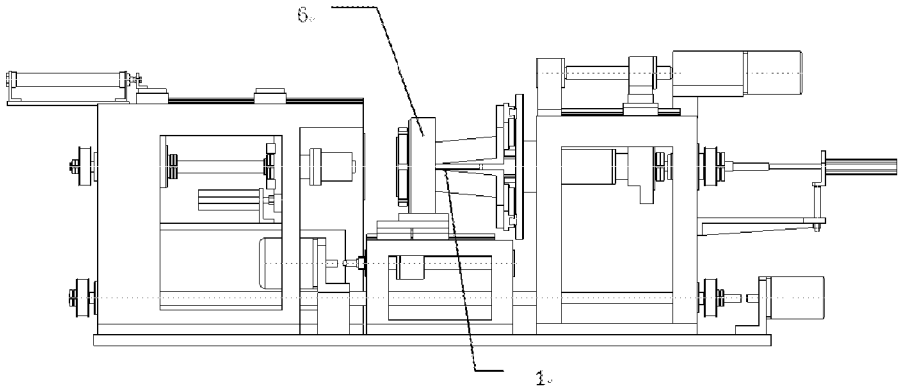

FIG. 1

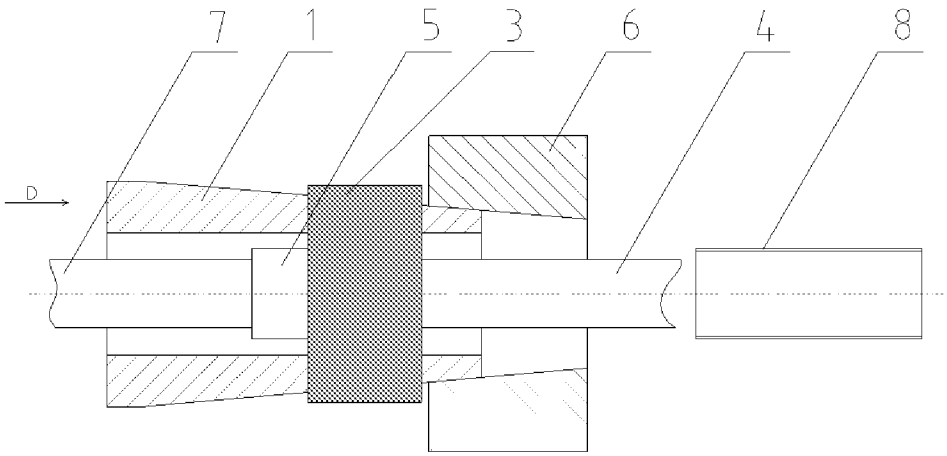

FIG. 2

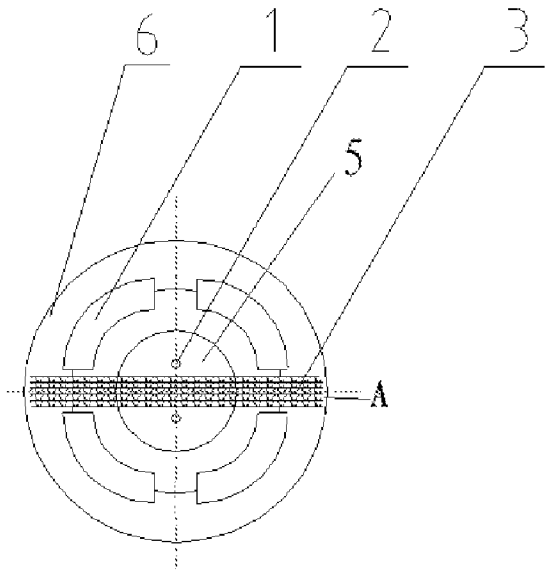

FIG. 3

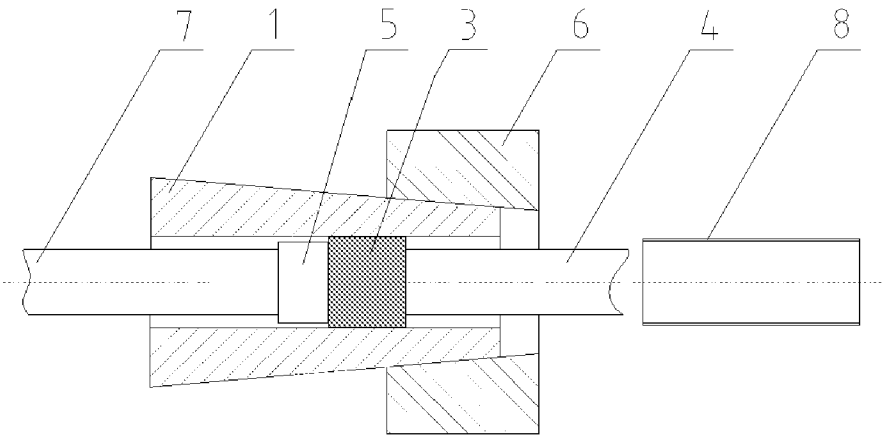

FIG. 4

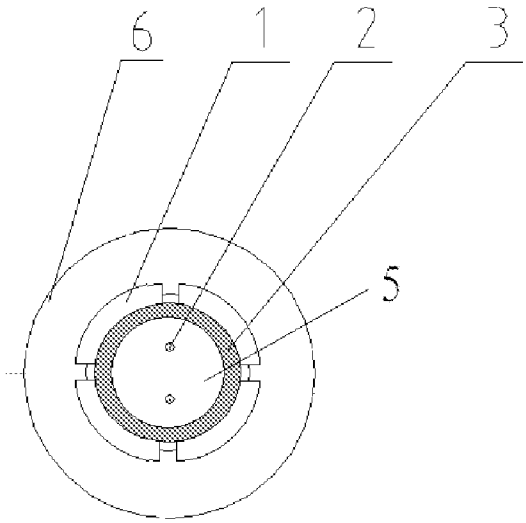

FIG. 5

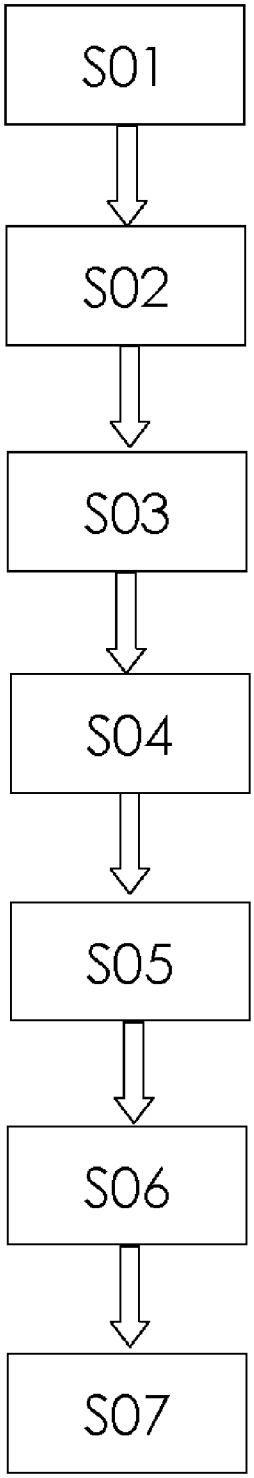

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2011/081618

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

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: F01N-, B01J-

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

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

CNKI; CNPAT; WPI; EPODOC: honeycomb, mold, mould, tighten+, roll+, rotat+, pin

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN101869952A (JIANGNAN UNIVERSITY) 27 Oct. 2010 (27.10.2010) paragraph [0029] to paragraph [0032] of the description and figures 1-6	1-9
A	US2010/0064496A1 (TSUCHIYA, Takashi et al.) 18 Mar. 2010 (18.03.2010) the whole document	1-9
A	CN1891989A (HAN, Zhao) 10 Jan. 2007 (10.01.2007) the whole document	1-9
A	CN101251036A (XIA, Qi) 27 Aug. 2008 (27.08.2008) the whole document	1-9
A	CN1187784A (EMISSION TECH. CO., LTD.) 15 Jul. 1998 (15.07.1998) the whole document	1-9

☐ 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 Jul.2012 (06.07.2012)	**16 Aug. 2012 (16.08.2012)**
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer YANG, Lin Telephone No. (86-10)62412854

Form PCT/ISA /210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2011/081618

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN101869952A	27.10.2010	NONE	
US2010/0064496A1	18.03.2010	WO2006/137456A1	28.12.2006
		JP2007-710A	01.11.2007
		JP2007-708A	01.11.2007
		DE112006001626T5	30.04.2008
		CN101203308A	18.06.2008
		BRPI0611990A	13.10.2010
		CN101875018A	03.11.2010
CN1891989A	10.01.2007	NONE	
CN101251036A	27.08.2008	NONE	
CN1187784A	15.07.1998	DE19521685A1	19.12.1996
		WO97/00135A1	03.01.1997
		AU5818796A	15.01.1997
		EP0831969A	01.04.1998
		BR9608354A	28.07.1998
		MX9710014A	31.07.1998
		JPH11-508814A	03.08.1999
		ES2137707T3	16.12.1999
		US6049961A	18.04.2000
		RU2154528C2	20.08.2000
		US6505396B1	14.01.2003
		IN191301A	15.11.2003

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2011/081618

Continuation of : CLASSIFICATION OF SUBJECT MATTER

F01N3/28 (2006.01) i

B01J35/04 (2006.01) i