US 20110206896A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2011/0206896 A1
(43) Pub. Date: Aug. 25, 2011
Humphrey et al.

(54) **CERAMIC HONEYCOMB BODY AND PROCESS FOR MANUFACTURE**

(76) Inventors: **Mark Lee Humphrey**, Elmira, NY (US); **James Willis Suggs, JR.**, Horseheads, NY (US)

(21) Appl. No.: **12/712,727**

(22) Filed: **Feb. 25, 2010**

Publication Classification

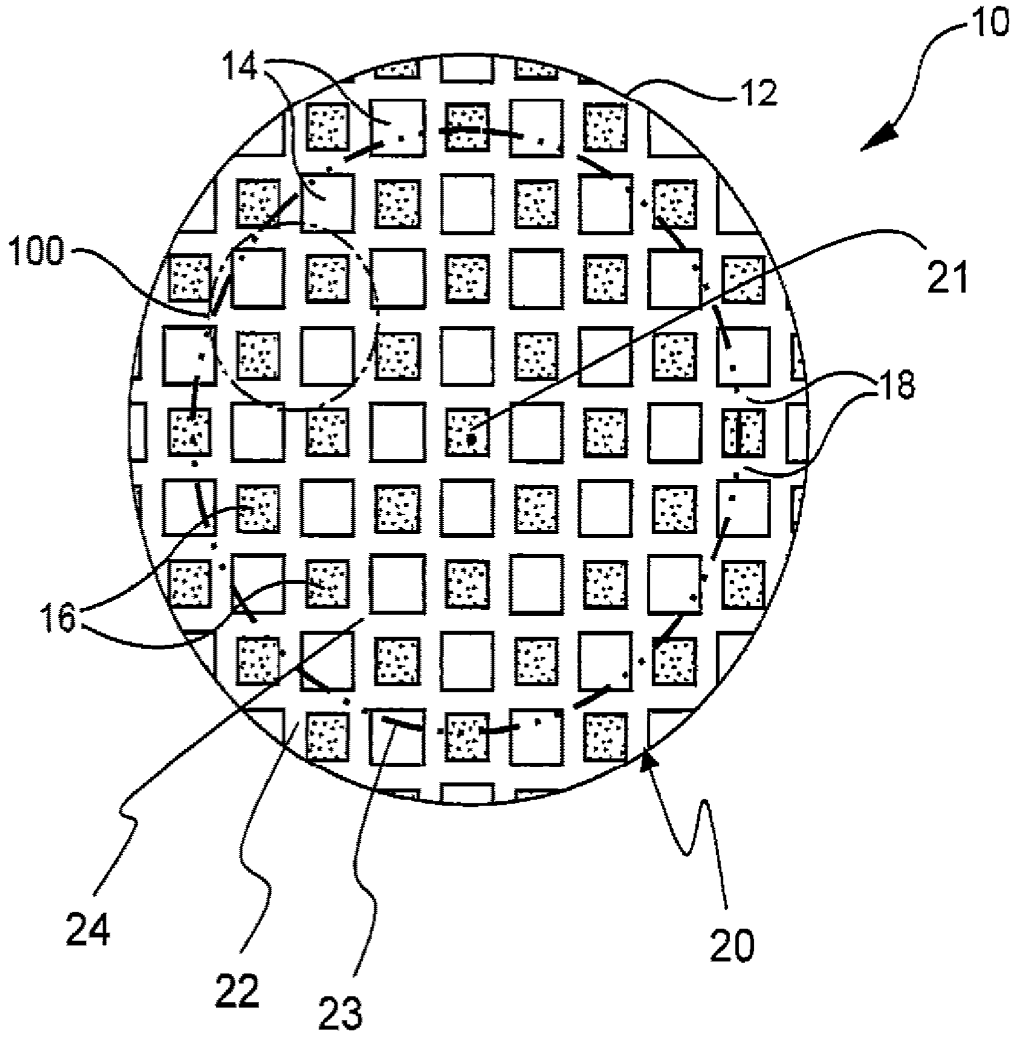
(51) **Int. Cl.**

B32B 3/12	(2006.01)
B29C 47/30	(2006.01)
H01R 43/00	(2006.01)

(52) **U.S. Cl.** **428/117**; 428/116; 425/464; 29/825

(57) **ABSTRACT**

An extrusion die and method for manufacturing an extrusion die for producing a honeycomb body. The honeycomb body includes a plurality of channels defined by intersecting internal walls. The channels have non-equal cross-sectional sizes arranged in an alternating pattern. The channels are divided into a first region including at least one row of channels adjacent an outer peripheral wall of the body, and a second region including remaining channels. The internal walls in the first region have a thickness that increases along an axis extending to the outer peripheral wall.



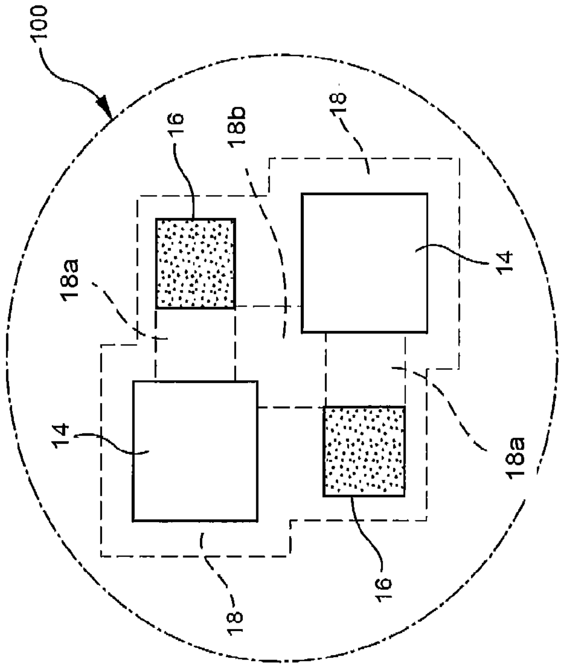


FIG. 2

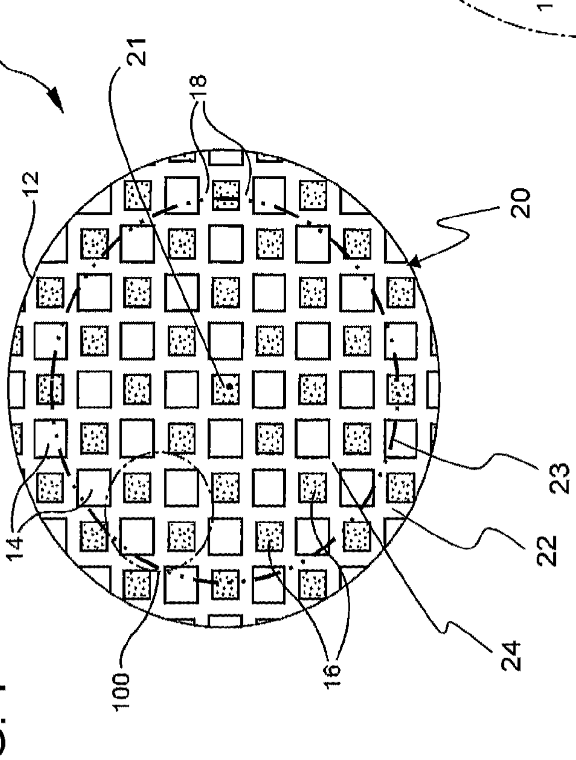


FIG. 1

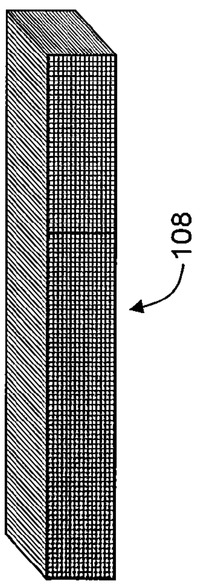


FIG. 4A

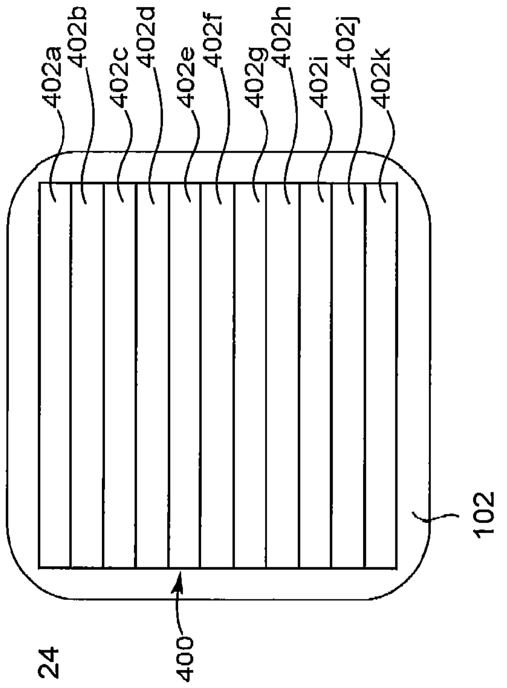


FIG. 4B

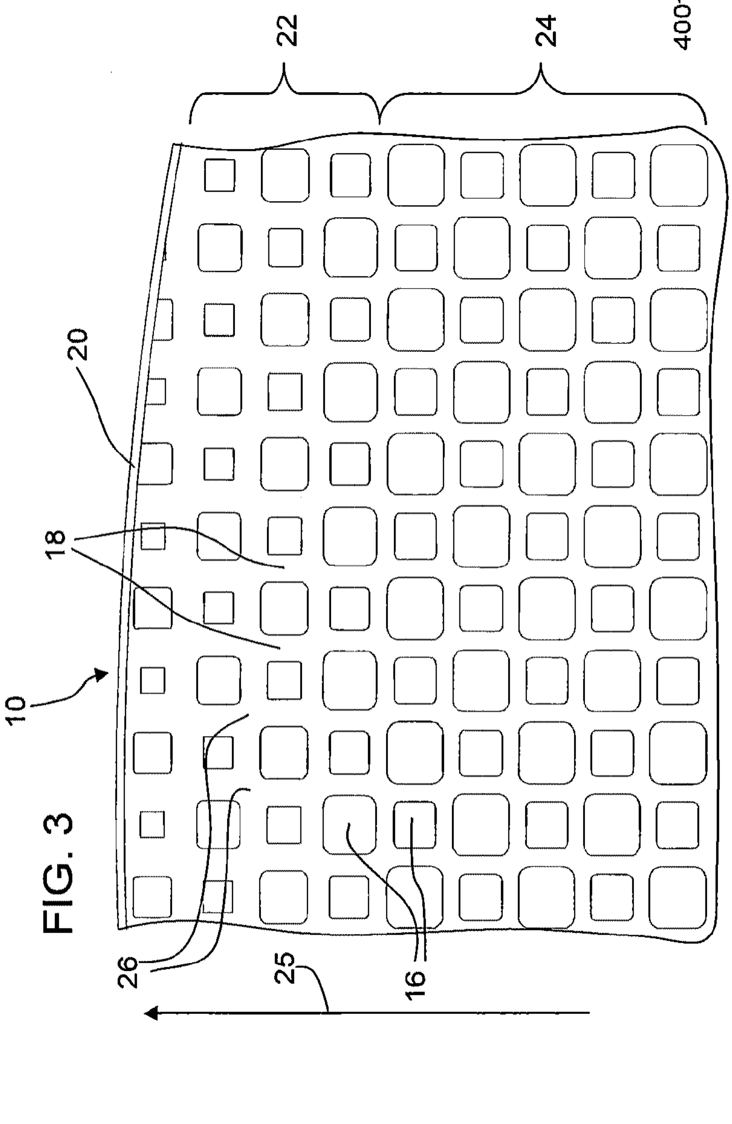


FIG. 3

FIG. 6

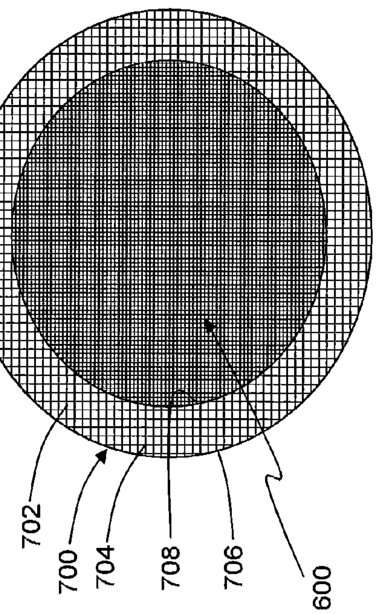


FIG. 7A

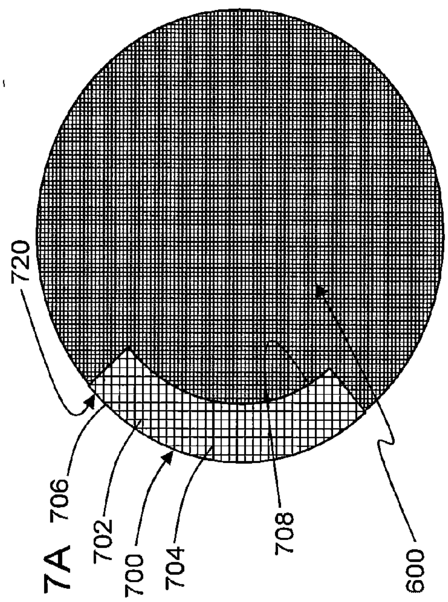
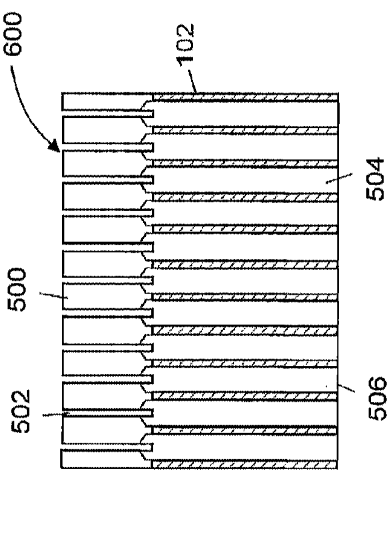


FIG. 5



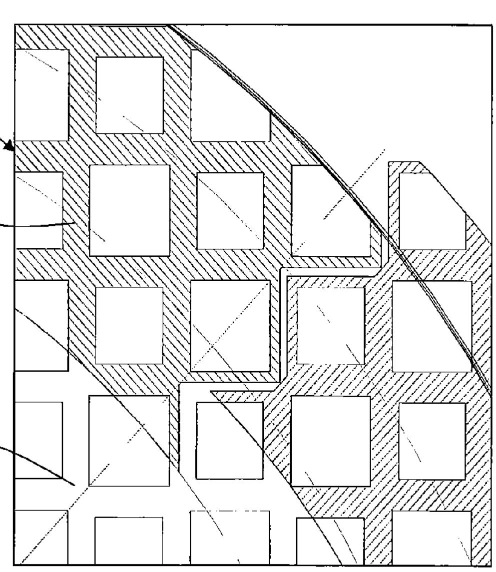

720
704
502
502

FIG. 7C

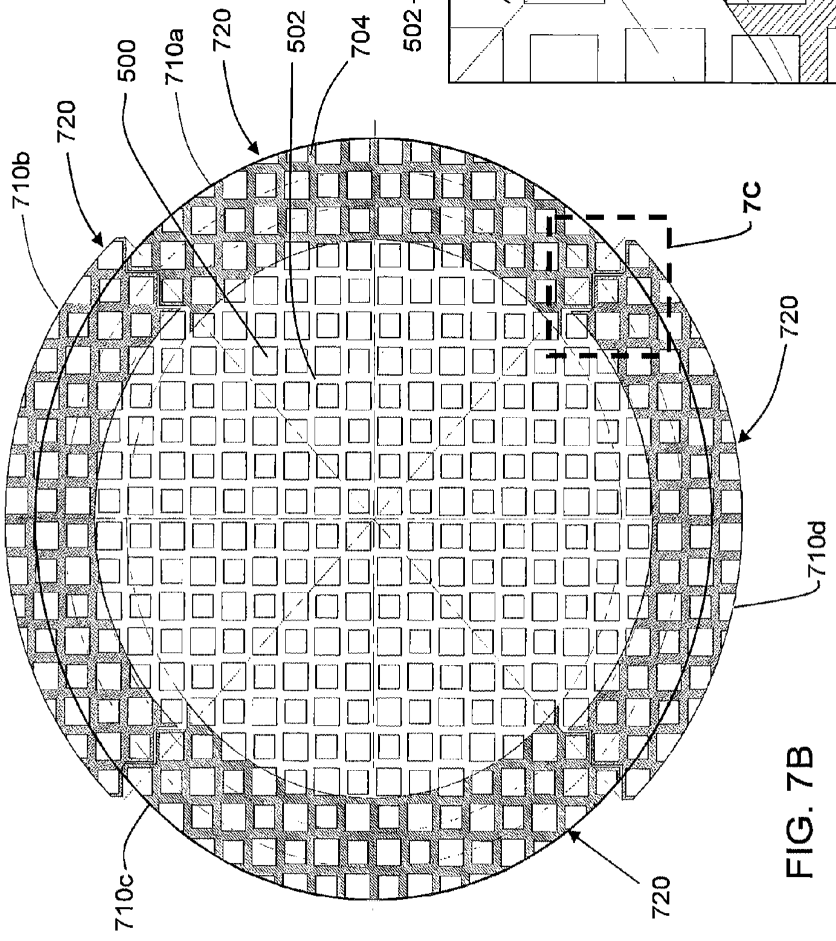
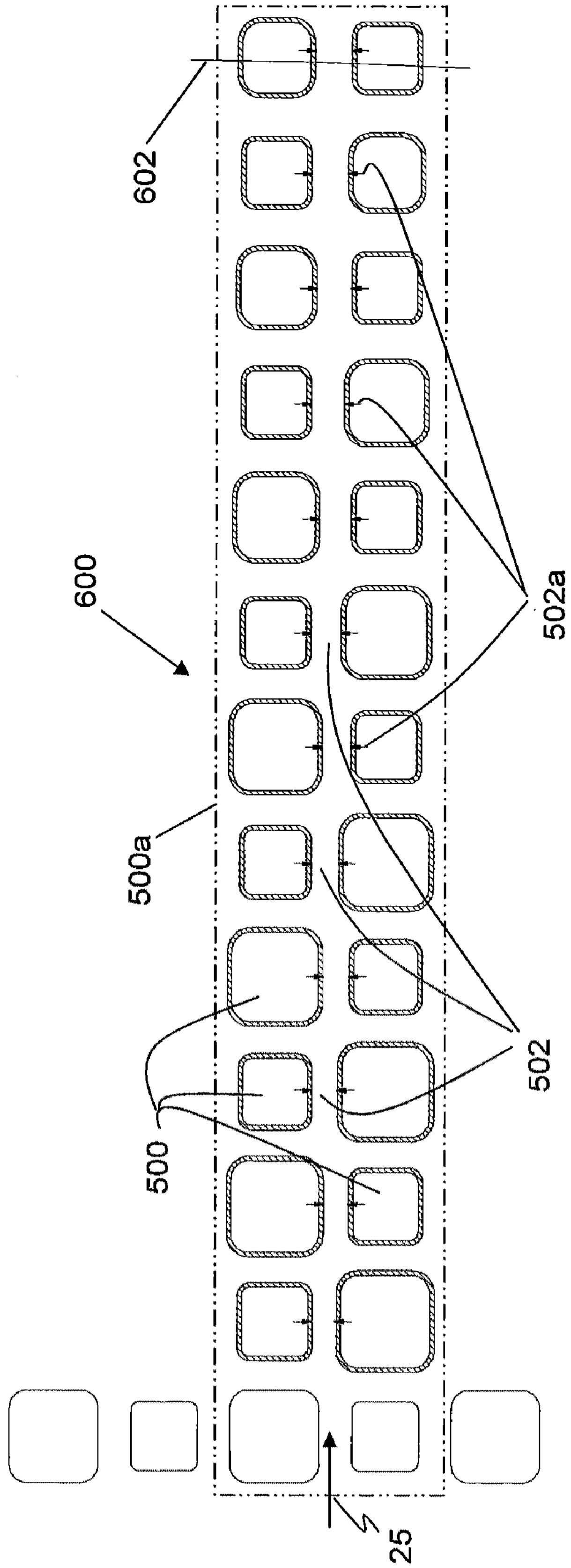

710b
720
500
710a
720
502
704
7C
720
710d
710c
720

FIG. 7B

FIG. 8



CERAMIC HONEYCOMB BODY AND PROCESS FOR MANUFACTURE

BACKGROUND

[0001] This disclosure relates generally to ceramic honeycomb bodies and processes for manufacture of such bodies. More particularly, the disclosure relates to electro discharge machining (EDM) processes for making a honeycomb extrusion die for the manufacture of honeycomb bodies having alternating channel sizes and varying wall thicknesses.

[0002] Honeycomb bodies used in catalyst substrate and particulate filtration applications consist of a monolith body having longitudinal, parallel channels defined by longitudinal interconnected webs. The honeycomb bodies are typically made by extruding a plasticized batch material that forms a ceramic material such as cordierite, aluminum titanate or silicon carbide after firing. Extrusion dies used in making the honeycomb bodies have a die body with a discharge end including an array of longitudinal pins defined by interconnected slots. The array of longitudinal pins may include pins having any geometry useful in catalyst substrate and particulate filtration applications, such as rectangular, triangular, or hexagonal. The inlet end of the die body includes feedholes which extend from a base of the die body to the interconnected slots and are used to supply batch material to the slots. To make a honeycomb body using the extrusion die, plasticized batch material is supplied to the feedholes and extruded through the interconnected slots. The batch material extruded through the interconnected slots forms the interconnected webs of the honeycomb body.

[0003] In some embodiments, the pins of an extrusion die have a uniform cross-sectional shape and size across the discharge end, while other embodiments employ pins having different cross-sectional shapes or sizes across the discharge end. In some embodiment, the interconnected slots have a uniform width across the discharge end, while other embodiments employ interconnected slots having different or varying widths across the discharge end.

[0004] Honeycomb extrusion dies are commonly made using plunge EDM processes. In a typical plunge EDM process, a shaped electrode having the desired pin/slot pattern is closely spaced from a workpiece that will become the extrusion die in a bath of dielectric fluid. The pin/slot pattern is formed in the workpiece by a series of repetitive electrical discharges in the thin gap between the shaped electrode and the workpiece. The electrical discharges generate enough heat to melt the workpiece and transfer the pin/slot pattern of the electrode to the workpiece.

[0005] The manufacture of honeycomb structures having varying channel sizes and wall thicknesses presents unique challenges, and innovative processes are needed for the efficient manufacture of such structures.

SUMMARY

[0006] One aspect of the disclosure includes a honeycomb body. In one embodiment described herein, a honeycomb body comprises a plurality of parallel channels defined by intersecting internal walls extending between opposing ends of the honeycomb body. The channels have non-equal cross-sectional sizes arranged in an alternating pattern. An outer peripheral wall surrounds the channels and is interconnected to the internal walls. The channels are divided into a first region including at least one row of the channels adjacent the outer peripheral wall, and a second region including remaining channels. The internal walls in the first region have a thickness that increases along an axis extending to the outer peripheral wall.

[0007] A further aspect of the disclosure includes a honeycomb extrusion die. In one embodiment, a honeycomb extrusion die comprises a die body having an inlet face and a discharge face opposite the inlet face. A plurality of feedholes extends from the inlet face into the body, and an intersecting array of discharge slots extend into the body from the discharge face. The array of discharge slots connects with the feed holes at feed hole/slot intersections within the die body. The intersecting array of discharge slots define a plurality of pins of two different cross-sectional areas, the plurality of pins forming a checkerboard matrix of pins alternating in cross-sectional area. A width of the discharge slots increases along an axis extending to an outer periphery of the die.

[0008] A further aspect of the disclosure includes a method of manufacturing an extrusion die. In one embodiment, a method of manufacturing an extrusion die comprises providing a die blank and forming a die pattern having a plurality of intersecting discharge slots of uniform width in a face of the die blank by plunging a first EDM electrode into the die blank. The intersecting discharge slots form side surfaces of a plurality of die pins having two different cross-sectional areas, the plurality of die pins forming a checkerboard matrix of pins alternating in size. The die pattern is divided into a first region including the slots and pins adjacent the periphery of the die, and a second region including the remaining slots and pins in the die pattern. The first region of the die pattern is modified by plunging a second EDM electrode into the first region of the die pattern.

[0009] Additional features and advantages will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the embodiments as described herein, including the detailed description which follows, the claims, as well as the appended drawings.

[0010] It is to be understood that both the foregoing general description and the following detailed description are merely exemplary, and are intended to provide an overview or framework to understanding the nature and character of the claims. The accompanying drawings are included to provide a further understanding, and are incorporated in and constitute a part of this specification. The drawings illustrate one or more embodiment(s), and together with the description serve to explain principles and operation of the various embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The accompanying drawings, described below, illustrate exemplary embodiments of the claimed invention and are not to be considered limiting, for the disclosure describes other equally effective embodiments and features thereof. The figures are not necessarily to scale, and certain features and certain view of the figures may be shown exaggerated in scale or in schematic in the interest of clarity and conciseness.

[0012] FIG. **1** is an illustration of a honeycomb article having inlet and outlet channels of alternating size.

[0013] FIG. **2** is a greatly enlarged portion of the inlet face of the honeycomb article of FIG. **1**, illustrating one embodiment of inlet and outlet channels of alternating size

[0014] FIG. **3** is a cross-sectional portion of the honeycomb article of FIG. **1**, illustrating the varying (increasing) wall thickness as the walls approach the outer periphery of the honeycomb article.

[0015] FIG. **4**A schematically depicts a plunge electrode having a plurality of interconnecting webs for forming a die pattern on a workpiece.

[0016] FIG. **4**B depicts electrode plunge locations forming a die pattern on a workpiece.

[0017] FIG. **5** illustrates a cross-section of a portion of an extrusion die.

[0018] FIG. **6** schematically illustrates a die modification electrode performing a secondary EDM machining process on an extrusion die.

[0019] FIG. **7**A schematically illustrates a ¼ pattern die modification electrode performing a secondary EDM machining process on an extrusion die.

[0020] FIG. **7**B illustrates four different positions occupied by a single ¼ pattern electrode when modifying the entire periphery of a die, with adjacent plunge positions offset from each other for proper alignment with alternating pin sizes.

[0021] FIG. **7**C shows a greatly enlarged portion of the ¼ pattern die modification electrode of FIG. **7**B, illustrating offset of the electrode in adjacent plunge locations.

[0022] FIG. **8** illustrates a portion of a die modification electrode for providing increasing wall thickness adjacent the periphery of a honeycomb body.

DETAILED DESCRIPTION

[0023] Reference will now be made in detail to exemplary embodiments which are illustrated in the accompanying drawings. In describing the embodiments, numerous specific details are set forth in order to provide a thorough understanding to the reader. However, it will be apparent to one skilled in the art that some or all of these specific details may not be necessary. In other instances, well-known features and/or process steps have not been described in detail so as not to unnecessarily obscure aspects of the exemplary embodiments. Whenever possible, the same reference numerals will be used throughout the drawings to refer to the same or like parts.

[0024] A top view of an end-plugged honeycomb structure with cell channels having two different cross-sectional sizes that provide two different hydraulic diameters is illustrated in FIG. **1**. Honeycomb **10** has a front or inlet end **12**, and an outlet end (not shown) opposite the inlet end **12**. A plurality of cell channels which are divided into inlet cell channels **14** and outlet cell channels **16** extend between the inlet and outlet ends. The cell channels have a generally square cross-section formed by interior porous walls **18**. Interior walls **18** extend substantially longitudinally between the inlet and outlet ends of the honeycomb **10**. The cell channels **14**, **16** are arranged to alternate between inlet cell channels **14** and outlet cell channels **16**, resulting in a pattern of alternating cell channels with small and large sizes. In the illustrated embodiment, each inlet cell channel **14** is bordered on all sides by outlet cell channels **16** and vice versa. An outer peripheral wall **20** surrounds the cell channels **14**, **16** and interior walls **18**. Outer peripheral wall **20** also forms what is commonly referred to as the "skin" of honeycomb **10**.

[0025] Both inlet cell channels **14** and outlet cell channels **16** are plugged along a portion of their lengths, either at the inlet end **12** or the outlet end. In FIGS. **1** and **2**, inlet end **12** is illustrated, so plugged outlet cell channels **16** are seen. That is, inlet cell channels **14** are open at the inlet end **12** and plugged at the outlet end. Conversely, outlet cell channels **16** are plugged at the inlet end **12** and open at the outlet end. This "checkerboard" plugging configuration allows more intimate contact between the fluid stream and the porous walls of the structure. The exhaust gas fluid stream flows into the honeycomb **10** through inlet cell channels **14**, then through the porous cell walls **18**, and out of the honeycomb **10** through the outlet cell channels **16**. Of course, different plugging patterns than that shown may be utilized, and in some embodiments, a portion of channels **14**, **16** may be completely unobstructed so as to form a partial filter.

[0026] FIG. **2** illustrates a close-up view of a small section **100** of FIG. **1** and better shows the structure of the alternating sizes of cell channels **14**, **16** in honeycomb **10**. A first portion of the interior walls **18** is common to both inlet **14** and outlet **16** cells. This portion depicted by the numeral **18***a* resides between entire length of outlet cells **16**, but only between part of inlet cells **14**. Portion **18***a* of interior wall **18** is preferably filtration active, meaning that in operation engine exhaust gases flow therethrough from the inlet passages **14** to outlet passages **16**. The remaining portion **18***b* of the interior walls **18** engages the section of inlet passages **14** not in communication with outlet passages **16**. Interior wall portion **18***b* may be filtration non-active, meaning that in operation exhaust gases are less likely to flow therethrough from inlet passages **14** to reach outlet passages **16**. It is to be noted, however, that some carbonaceous and ash particulates may be captured and collected therein. In one embodiment, the cross-section or hydraulic diameter of inlet cell channels **14** is about 1.1-2.0 times greater than the hydraulic diameter of the outlet cell channels **16**. In another embodiment, the cross-section or hydraulic diameter of inlet cell channels **14** is about 1.3-1.6 times greater than the hydraulic diameter of the outlet cell channels **16**. In one embodiment, honeycomb **10** has a cell density of about 100-300 cells/in^2 (15.5-46.5 cells/cm^2), although cell densities above and below that range are also contemplated. In one embodiment, honeycomb **10** has a wall thickness about 0.001 to 0.025 inches (0.25-0.64 mm), although wall thicknesses above and below that range are also contemplated. It should be noted that for purposes of illustration, the sizes and proportions of some features of honeycomb **10** as shown in the Figures are greatly exaggerated and not to scale.

[0027] Referring again to FIG. **1**, a phantom line **23** is drawn as an illustrative example of how cell channels **14**, **16** are suitably divided into first region **22** and a second region **24**. Specifically, first region **22** comprises cell channels **14**, **16** adjacent the outer peripheral wall **20**, and second region **24** comprises the remaining cell channels **14**, **16** toward the center axis **21**. In FIG. **1**, the relative scale of features of honeycomb **10** are distorted (specifically the size and number of cell channels **14**, **16**). However, in one embodiment, first region **22** comprises at least one row of channels **14**, **16** adjacent outer peripheral wall **20**, although in other embodiments first region **22** may comprise more than four rows, more than seven rows, more than ten rows, or even more than twenty rows adjacent outer peripheral wall **20**.

[0028] Referring to FIG. **3**, a greatly enlarged portion of honeycomb **10** adjacent outer peripheral wall **20** is schematically illustrated. As can be seen in FIG. **3**, cells **14**, **16** in the first region **22** have a wall thickness which increases along an axis extending toward the outer peripheral wall **20** as indicated by arrow **25**, such that interior walls **18** become thicker as they approach outer peripheral wall **20**. In one embodiment, the thickness of walls **18** in first region **22** increases to be 1.01 to four (4) or more times the thickness of walls **18** in second region **24**, such as near axis **21**. It has been found that thickening walls **18** near the outer peripheral wall **20** provides increased isostatic strength to honeycomb **10** without a detrimental effect on the thermal shock resistance of honeycomb **10**, and also has a minimum effect on the pressure drop.

[0029] In one embodiment, as shown in FIG. **3**, fillets **26** are formed in the cell channels **14**, **16** at least at junctions or intersections between walls **18** in first region **22**. Fillets may also be formed at junctions of walls **18** in second region **24**, and at junctions of walls **18** with the outer peripheral wall **20**. In one embodiment, fillets at the junctions of walls **18** remain the same in first and second regions **22**, **24**, although the radius of fillets for cell channels **14** may differ from that of cell channels **16**. In another embodiment, fillets closer to the outer peripheral wall **20** may have a radius that is greater than the radius of fillets close to the center axis **21** of the honeycomb **10**.

[0030] A suitable method for fabricating the honeycomb **10** with alternating channel sizes and wall thicknesses that increase near outer peripheral wall **20** as described above is by forming a plasticized mixture of powdered raw materials which is then extruded through a die into a honeycomb body with alternating cell channel sizes and varying wall thicknesses, then optionally dried, fired and plugged using known apparatuses and processes to form the plugged honeycomb filter. The plugged honeycomb filter is typically mounted (such as on a vehicle) by positioning the filter snugly within a filter enclosure with a refractory resilient mat disposed between the filter sidewall and the wall of the enclosure. The ends of the enclosure may then be provided with inlet and outlet cones for channeling exhaust gas into and through the alternately plugged channels and porous wall of the honeycomb filter.

[0031] An extrusion die for fabricating the honeycomb **10** with alternating channel sizes and increasing wall thicknesses near outer peripheral wall **20** as described above will have a corresponding pin array comprising pins of alternating size separated by discharge slots, where the discharge slots gradually widen in a direction along an axis extending to the outer periphery of the die. One method for fabricating such a die is a plunge EDM process.

[0032] Referring to FIGS. **4**A and **4**B, in a plunge EDM process, a shaped electrode **108** having a pattern of features is used for machining those features into a workpiece **102** (sometimes referred to as a die blank) that will eventually become the die. A suitable electrical discharge electrode **108** for carrying out the plunge EDM method can be formed from a copper-tungsten alloy blank using traveling wire electrical discharge machining (wire EDM), as known in the art. Other suitable materials for electrode **108** include silver-tungsten, graphite, and copper-graphite, for example. In use, the electrode **108** is positioned close to the workpiece **102**, and features of the electrode **108** are machined into the workpiece **102** through repetitive electrical charges discharged into a gap between the electrode **108** and the workpiece **102**. For example, as shown in FIG. **4**A, for a honeycomb extrusion die having a lattice of interconnected webs, the shaped electrode **108** includes a lattice of interconnected webs forming a honeycomb pattern or a portion of a honeycomb pattern. The shaped electrode **108** is configured to form multiple features (e.g., multiple rows and columns of pins and slots) at a time. In general, the shaped electrode **108** may be configured to form patterns with features of any desired shape. In one example, the pattern to be formed in workpiece **102** by electrode **108** is an array of alternating size pins separated by slots of uniform width.

[0033] In FIGS. **4**A and **4**B, the electrode **108** is illustrated as having an overall rectangular shape corresponding to a rectangular shape that is some fraction of the full die pattern **400** (FIG. **4**B). Depending on the final die size, the width of the electrode **108** may correspond to the full width of the die pattern **400**, one half the width of the die pattern, or some smaller fraction. FIG. **4**B illustrates a full die pattern **400** on workpiece **102**, with plunge locations **402***a*-**402***k* (collectively plunge locations **402**) on the workpiece **102**. There are eleven plunge locations **402** illustrated in FIG. **4**B, but any other number of plunge locations **402** may be used. The number of plunge locations **402** will depend, for example, on the size of the full die pattern **400** and the size of electrode **108**.

[0034] FIG. **5** shows an exemplary illustration of a cross-section of the workpiece **102** after forming pins **500** and slots **502** in the workpiece **102** using a plunge EDM process as described above. To complete formation of an extrusion die, feedholes **504** can be formed in the workpiece **102**, and the final die **600** may be cut from the workpiece in any desired shape (e.g., circular, oval, rectangular, etc.). A circular die **600** cut from workpiece **102** is illustrated in FIG. **6**. The feedholes **504** would typically extend from the base **506** of the workpiece **102** to the slots **502** in order to allow plasticized batch material to be supplied to the slots **502** and extruded therethrough. The workpiece **102** with the pins **500**, slots **502**, and feedholes **504** may serve as a template for other honeycomb extrusion dies. For example, the pins **500** may be modified as necessary to achieve other geometries more suitable for a particular application.

[0035] The EDM die manufacturing process described above provides a die with a pin array having discharge slots with a uniform width across the discharge face of the die. Therefore, to provide honeycomb **10** with walls **18** having increasing thickness as they approach outer peripheral wall **20**, there is a need to further modify the widths of discharge slots **502** in the die at locations corresponding to second region **24** of honeycomb **10**. Such modification may be accomplished with a die modification electrode **700** performing a secondary die modification plunge EDM process.

[0036] Since the only a portion of the discharge slots **502** (i.e., those corresponding to second region **24**) require modification, a die modification electrode **700** used in a secondary plunge EDM process need only encompass that area of the die where the modifications are to occur. Specifically, widening the discharge slots **502** adjacent the outer periphery of the die requires that a plurality of pins in the second region **24** of the die (adjacent outer peripheral wall **20**) be further machined by the die modification electrode.

[0037] FIGS. **6** and **7**A schematically shows a die **600** and embodiments of a die modification electrode **700** in accordance with the present disclosure. Die **600** comprises pins **500** and discharge slots **502** previously machined by shaped electrode **108**. Die modification electrode **700** includes openings **702** formed by a network of intersecting webs **704**. Webs **704** have an increasing width as they approach the outer edge **706** of electrode **700**, which stands opposite inner edge **708** of electrode **700**. The width of webs **704** is increased from the nominal (original) thickness of discharge slots **502** to the desired thickness at the periphery of the die **600** in either a continuous or a stepped manner. For example, in one embodiment, the width of webs **704** (and also the width of corresponding slots **502**) is increased at each subsequent pin location by a predetermined amount (e.g., 0.5 mil, 0.75 mil, 1 mil, or any other selected amount). In one embodiment, the increase in width becomes larger as the web **704** reaches the outer edge **706** of electrode **700**. For example, if electrode **700** is configured to modify 10 rows of pins **500**, the width of web **704** may be increased by 0.5 mils for each of the first 4 pins, 0.75 mils for each of the next 4 pins, and 1 mil for the final 2 pins. Of course, a limitless number of other such examples with different distances and pin numbers can be constructed.

[0038] During the die modification plunge EDM process, die **600** is held stationary while electrode **700** is lowered on the array of pins **500**. When electrode **700** is lowered into the array of pins **500**, the webs **704** being thicker than pre-existing slots **502** remove material from all side surfaces of pins **500**. If the corners of intersecting webs **704** are filleted, material will also be removed from the corners of pins **500**. As a result, pre-existing slots **502** are machined to become wider by narrowing surrounding pins **500**. If so provided, the filleted corners of webs **704** radius the corners of pins **500** to create fillets in the extruded honeycomb. Depending on the number of pin rows requiring modification, the size of electrode **700**, along with the number of openings **702** and thickness of webs **704** is varied accordingly.

[0039] The die modification plunge EDM process does not alter the inlet or feedhole section of the die **600** in any way, nor is there any change to the inlet section of the die required. The geometry of the extruded honeycomb **10** produced from a machined die of this design has alternating channel sizes with continuously thickening walls in a region of cells adjacent an outer peripheral wall **20** of the honeycomb **10**.

[0040] In the embodiment of FIG. **6**, die modification electrode **700** comprises a single structure that circumscribes the entire periphery of die **600**. However, one skilled in the art can appreciate the complexity and high cost in fabricating such an electrode due to the many precision machining steps required. Creating a unitary electrode encompassing the entire 360° pattern may be excessively costly, and include risks of high variability and risk of scrapping due to unforeseen upsets during the electrode manufacturing process, such as tool breakage, power failures, etc., as well as human error.

[0041] For these reasons, in another embodiment as illustrated in FIGS. **7**A through **7**C, die modification electrode **700** comprises a ¼ pattern electrode **720** (i.e., electrode **720** circumscribes a 90° arc about the periphery of die **600**) that is plunged, retracted, rotated and plunged again until the entire periphery of die **600** has been machined. The ¼ pattern die modification electrode **720** is a cost-effective solution to the issues mentioned above.

[0042] However, because of the alternating pin sizes of die **600**, a ¼ pattern electrode/four rotation plunge EDM die modification process presents a unique challenge in aligning the alternating sizes of the openings in the ¼ pattern die modification electrode **720** with the alternating sizes of pins **500** when moving from one plunge location to the next. Specifically, the alternating large channel/small channel pattern of die **600** causes misalignment with the ¼ pattern electrode **720** at the plunge intersections if the electrode **720** is simply rotated 90° to the next plunge location. That is, a ¼ pattern electrode **720** for machining alternating pin sizes will only properly align if it is rotated 180° (thus skipping a 90° arc therebetween). One option for solving this problem is through the use of two different ¼ pattern electrodes, where the two different electrodes are shaped to cover two opposing 90° arcs of the die periphery. While the use of two unique ¼ pattern electrodes will solve the alignment problem, that solution adds the complexity and cost of: 1) fabricating a second electrode; and 2) increased processing time due to additional tooling changeover and setup required for the second ¼ pattern electrode. The additional steps also provide increased opportunity for error to be introduced into the process.

[0043] Accordingly, this disclosure provides a solution to the above-described die modification electrode alignment issue and enables the use of a single ¼ pattern electrode **720**. Proper alignment between the ¼ pattern electrode **720** and the die **600** is accomplished by offsetting the location of the ¼ pattern electrode **720** when positioning for the next plunge location. Referring to FIGS. **7**B and **7**C, one possible example of such offsetting is shown. Specifically, the electrode **720** is moved in or out by one or more rows from adjacent plunge locations **710***a*, **710***b*, **710***c* and **710***d*, such that the webs **704** of electrode **720** align with the discharge slots **502** of die **600**. In one embodiment, as shown in FIGS. **7**A-**7**C, plunge locations **710***a*, **710***b*, **710***c* and **710***d* are located such that ends of the ¼ pattern electrode **720** are positioned at 45° angles with respect to the orientation of the pins **500** and slots **502** of die **600**. The offset between adjacent plunge locations enables the use the same ¼ pattern electrode **720** for all four locations **710***a*, **710***b*, **710***c*, **710***d*. As seen in FIG. **7**C, the ends of electrode **720** are provided with a "zig-zag" shape such that matching to adjacent plunge locations is provided.

[0044] To modify pins **500**, die modification electrode **700**/**720** is used to remove material from the sides of the pins **500**. FIG. **8** shows a portion of a die **600** in which a plurality of pins **500** (inside the dashed box **500***a*) have been machined according to the die modification plunge EDM process and die modification electrode **700** described herein. The modified pins **500** have a smaller size, which results in increasingly wider discharge slots **502** as shown at the arrows designated by reference numeral **502***a*. Discharge slots **502** gradually widen in a direction along axis **25** extending to the outer periphery of the die **600** (designated by line **602**).

[0045] While the claimed invention has been described herein with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope of the invention as claimed herein. Accordingly, the scope of the invention should be limited only by the attached claims.

What is claimed is:

1. A honeycomb body comprising:

a plurality of parallel channels defined by intersecting internal walls extending between opposing ends of the honeycomb body, wherein the channels have non-equal cross-sectional sizes arranged in an alternating pattern; and

an outer peripheral wall surrounding the channels and further being interconnected to the internal walls;

wherein the channels are divided into a first region including at least one row of the channels adjacent the outer peripheral wall, and a second region including remaining channels; and

wherein the internal walls in the first region have a thickness that increases along an axis extending to the outer peripheral wall.

2. The honeycomb body of claim 1, wherein the first region includes at least four rows of channels adjacent the outer peripheral wall.

3. The honeycomb of claim 1, wherein the internal walls in the first region have a thickness that is 1.01 to 4 times the thickness of internal walls in the second region.

4. The honeycomb body of claim 1, wherein the channels include inlet channels having a first cross-sectional area and outlet channels having a second cross-sectional area, wherein the second cross-sectional area is smaller than the first cross-sectional area, the inlet and outlet channels arranged in an alternating pattern, wherein the inlet channels are plugged at an outlet end of the honeycomb body, and the outlet channels are plugged at an inlet end of the honeycomb body.

5. The honeycomb body of claim 4, wherein the inlet cells have a hydraulic diameter 1.1-2 times greater than the outlet cells.

6. The honeycomb body of claim 1, wherein the honeycomb body is made of cordierite, aluminum titanate, or silicon carbide.

7. A honeycomb extrusion die comprising:
- a die body having an inlet face and a discharge face opposite the inlet face;
- a plurality of feedholes extending from the inlet face into the body;
- an intersecting array of discharge slots extending into the body from the discharge face to connect with the feed holes at feed hole/slot intersections within the die body, the intersecting array of discharge slots defining a plurality of pins of two different cross-sectional areas, the plurality of pins forming a checkerboard matrix of pins alternating in cross-sectional area; and
- wherein a width of the discharge slots increases along an axis extending to an outer periphery of the die.

8. The honeycomb extrusion die of claim 7, wherein the discharge face is divided into a first region including at least one row of pins adjacent the outer periphery of the die, and a second region including remaining pins; and wherein the width of discharge slots in the first region increases along an axis extending to the outer periphery of the die.

9. The honeycomb extrusion die of claim 8, wherein the first region includes at least four rows of pins adjacent the outer periphery of the die.

10. The honeycomb of claim 8, wherein the discharge slots in the first region have a width that is 1.01 to 4 times the width of discharge slots in the second region.

11. A method of manufacturing an extrusion die, the method comprising:
- providing a die blank;
- forming a die pattern having a plurality of intersecting discharge slots of uniform width in a face of the die blank by plunging a first EDM electrode into the die blank, wherein the intersecting discharge slots form side surfaces of a plurality of die pins having two different cross-sectional areas, the plurality of die pins forming a checkerboard matrix of pins alternating in size, wherein the die pattern is divided into a first region including the slots and pins adjacent the periphery of the die, and a second region including the remaining slots and pins in the die pattern; and
- modifying the first region of the die pattern by plunging a second EDM electrode into the first region of the die pattern.

12. The method of claim 11, wherein modifying the first region of the die pattern comprises increasing the width of the discharge slots in the first region along an axis extending to the periphery of the die.

13. The method of claim 11, wherein modifying the first region of the die pattern comprises plunging the second EDM electrode at a plurality of plunge locations around the periphery of the die.

14. The method of claim 13, wherein the second EDM electrode comprises a ¼ pattern of the first region, and wherein plunging the second EDM electrode at a plurality of plunge locations around the periphery of the die comprises plunging the second EDM electrode consecutively at each quarter section of the first region.

15. The method of claim 14, wherein for each consecutive plunge location the second EDM electrode is offset at least one pin row from a previous plunge location.

16. The method of claim 11, wherein the second EDM electrode has a shape that is complementary to a peripheral shape of the die.

17. The method of claim 16, wherein the second EDM electrode has a shape that is complementary to a fraction of the peripheral shape of the die.

18. The method of claim 17, wherein the second EDM electrode has a shape that is complementary to ¼ of the peripheral shape of the die.

19. The method of claim 11, wherein the first region includes at least one row of slots and pins adjacent the periphery of the die.

20. The method of claim 11, wherein the first region includes at least four rows of slots and pins adjacent the periphery of the die

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