AUSTRALIA
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APPLICATION FOR A STANDARD PATENT

General Motors Corporation
West Grand Boulevard and Cass Avenue, Detroit, Michigan, 48202,
UNITED STATES OF AMERICA

hereby applies for the grant of a standard patent for an invention entitled:

METHOD FOR MANUFACTURING A DIE FOR EXTRUDING HONEYCOMB MATERIAL

which is described in the accompanying complete specification.

Details of basic application(s):-
397,936 UNITED STATES OF AMERICA 24 August 1989

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DATED this NINTH day of AUGUST 1990

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By:

David P. Fitzpatrick

Our Ref: 184660
POF Code: 1221/1695
COMMONWEALTH OF AUSTRALIA
Patents Act
DECLARATION FOR A PATENT APPLICATION

In support of the (a) Convention application made by GENERAL MOTORS CORPORATION (hereinafter called "the applicant") for a patent (c) for an invention entitled:-

METHOD FOR MANUFACTURING A DIE FOR EXTRUDING HONEYCOMB MATERIAL

1. Arthur Donald Haines, Chartered Patent Agent of Patent Section Vauxhall Motors Ltd, 1st Floor, Gideon House, 26 Chapel Street Luton, Beds LU1 2SE do solemnly and sincerely declare as follows:-

1. I am authorized under a power of attorney from the applicant granted on 1st May 1981 to make this declaration on behalf of the applicant.


is/are the actual inventor(s) of the invention and the applicant is entitled to make the application by virtue of a service agreement(s) between the applicant and the inventor(s) as employee(s) and an assignment(s) from the inventor(s) to the applicant.

3. The basic application(s) for patent or similar protection on which the application is based is/are identified by country, filing date and basic applicant(s) as follows:

United States of America
24 August 1989
Richard F Beckmeyer

4. The basic application(s) referred to in paragraph 3 hereof was/were the first application(s) made in a Convention country in respect of the invention the subject of the application.

Declared at: Luton, England
Dated: 1 August 1990

For and on behalf of
GENERAL MOTORS CORPORATION

Under Power of Attorney
Claim

1. A method of making a die for extruding a body having a honeycomb structure, the die having a plurality of feed holes, an extrusion-slot pattern and a transition path for directing extrudant from the feed holes through the extrusion-slot pattern to form the shape of said honeycomb-structured body, said method comprising the steps of: stacking a plurality of individual tubes in spaced parallelism to one another to form a loose tube stack having a plurality of spaced parallel feed holes therein; providing a plurality of individual shaping teeth, each having a head portion and a shank portion; fixing each of said shaping teeth with respect to the other shaping teeth for providing accurate spacing between the head portions thereof for forming intersecting rows of extrusion slots; and inserting the shank portions of the fixed shaping teeth into said loose tube stack to produce accurate alignment of the shaping teeth with respect to the feed holes whilst conforming the intersecting rows of extrusion slots with the feed holes by adjusting the position of the loose individual tubes with respect to the fixed shaping teeth.
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COMPLETE SPECIFICATION
(ORIGINAL)

Application Number:    Class    Int. Class
Lodged:

Complete Specification Lodged:    Accepted:
Published:

Priority

Related Art:

Applicant(s):
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Complete Specification for the invention entitled:
METHOD FOR MANUFACTURING A DIE FOR EXTRUDING HONEYCOMB MATERIAL

Our Ref: 184660
POF Code: 1221/1695

The following statement is a full description of this invention, including
the best method of performing it known to applicant(s):

6006
METHOD FOR MANUFACTURING A DIE FOR EXTRUDING HONEYCOMB MATERIAL

This invention relates to extrusion dies for ceramic material or the like and to a method for manufacturing such dies. More particularly, it relates to a method of making extrusion dies of the type used in making ceramic monolithic honeycomb articles, such as those used in the catalytic treatment of automotive exhaust gases.

Background of the Invention

Monolithic bodies having longitudinal through passages are produced by forcing an extrudable plastic mixture of ceramic material through interconnecting die passages in which the material is shaped and coalesced into a structure of intersecting, relatively thin walls that define the passages of a honeycomb structure having a cell density which is established by the number of passages formed through a cross-section of a unit of the honeycomb structure. In one application the material is a mixture of materials, such as clay, talc and alumina, that can be fired to form cordierite or other heat-resistant ceramic.

The main purpose of such a honeycomb-type structure is to provide an extended surface area for exhaust gases to pass over. The surface area is increased by increasing the cell density, e.g., the number of cells per square centimetre through which the exhaust can flow. At the same time, it is usually necessary to form thinner cell walls of uniform thickness.

In certain cases the monolith consists of many longitudinal passages, as many as 62 per square centimetre (400 per square inch) of cross-section of
the monolith. In the extrusion process, a wet or green ceramic precursor mixture of a suitable length is formed. It is directed through an extrusion die to form a resultant honeycombed green extrusion.

The extrusion is sliced cross-ways to form several pieces which are dried and fired to form the monolith substrates. The internal walls of the substrates are then coated with a noble metal catalyst finely dispersed on a suitable wash coat. Such honeycombed substrates are oval or elliptical in cross-section and the individual cell cross-section is usually generally of square cross-section. The greatest dimension of the overall cross-section can be of the order of 15.24 centimetres (six inches) and the length of the monolith can be about 15.24 centimetres (six inches). The cell dimensions, however, are several orders of magnitude smaller, e.g., in the range of 0.11 centimetre (0.044 inch) square at the cell hole and with cell wall thicknesses of the order of 0.015 centimetre (0.006 inch). In order to extrude monoliths of this magnitude cell size at desired densities of the order of 62 cells per square centimetre (400 cells per square inch) and uniformly thin wall thicknesses, it is essential that the extrusion die be a precision die.

An example of such a die is set forth in U.S. Patent No.4,486,934 issued December 11, 1984 to James R. Reed. The Reed design represents a common prior-art extrusion die which, whilst suitable for its intended purpose, is of a configuration and is made by a method which is very complicated to form when bodies having 62 cells per square centimetre
(400 cells per square inch) are to be extruded therethrough. Use of known precision machining methods to form such high cell density, thin wall extrusion paths in prior-art extrusion dies involves considerable expense and difficulty.

**Summary of the Invention**

A feature of the present invention is to provide a method for manufacturing an extrusion die for honeycomb structures including a feed section and a forming section and wherein both the feed section and forming section are constructed from individual elements by a method which includes the steps of first loosely joining individual tube elements to form the feed section; thereafter fixing a plurality of shaping teeth together and thereafter inserting the fixed shaping teeth in the loosely-joined tube elements to form an extrusion slot with intersecting rows for shaping the extrudable material into a honeycomb structure of high cell density.

Another feature of the present invention is to provide a method for manufacturing an extrusion die for honeycomb structures including a feed section and a forming section and wherein both the feed section and the forming section are constructed from individual elements by a method which includes the steps of first loosely joining individual tube elements to form the feed section and thereafter the step of fixing a plurality of shaping teeth to form extrusion slot patterns therebetween and joining the fixed shaping teeth to the loosely-joined tube elements to conform the extrusion slot pattern to the
location of feed holes in the feed section and thereafter bonding the joined feed section and forming section together as a unitary extrusion die having an extrusion slot with intersecting rows for shaping the extrudable material into a honeycomb structure of high cell density.

Another feature of the present invention is to provide a method of the preceding paragraph wherein the individual tube elements are loosely joined as a stack of tubes.

Still another feature of the present invention is to provide the method of the preceding paragraph wherein the stacking includes location of a plurality of individual tubes in spaced parallelism to one another and engaging the outer surfaces of the tubes together to form a loose tube stack having a plurality of spaced parallel feed holes.

Yet another object of the present invention is to increase the accuracy of location between the feed section and the forming section by inserting shank portions of the fixed shaping teeth into the loose tube stack to produce accurate alignment of the shaping teeth with respect to the feed holes whilst conforming the intersecting rows of extrusion slots with the feed holes by adjusting the loose tube elements with respect to the fixed shaping teeth.

Another object of the invention is to provide a unitary extrusion die having accurate location between the feed section and the forming section by use of the preceding methods further characterized by bonding the individual shaping teeth and the loose tube stack together after
the fixed teeth are located therein to form a precise extrusion slot pattern with respect to the feed holes.

Still another object of the invention is to provide a unitary extrusion die having such an accurate location of components therein by use of the preceding method further characterized by fixing each of said shaping teeth together by use of removable retainer means which are bonded to the shaping teeth as the shaping teeth are bonded to the tube stack and thereafter removed from the shaping teeth with a portion of each of the shaping teeth to form the intersecting row pattern of the extrusion slots.

Another feature is to provide the method of the preceding object in which the method is further characterized by fixing the shaping teeth in spaced relationship to one another by locating them in a wire grid having spaced parallel row strips and spaced parallel rank strips.

Yet another feature of the invention is to simplify the preceding methods by providing an assembly sequence characterized by fixing the shaping teeth simultaneously whilst stacking the individual tube members so that a portion of the shaping teeth will space the individual tubes at interstices therebetween.

**Brief Summary of the Invention**

In accordance with a preferred embodiment of the present invention, these and other features, objects and advantages are accomplished as follows. An extrusion die is provided with a feed section
having a stack of tubes with abutting sections and spaced sections which are maintained in a spaced relationship by lengths of spacer wire which have a diameter less than that of the stacked tubes and are of a shorter length than the tubes. The spaced tubes have interstices formed at one end thereof defined by reference surfaces for a shank portion of individual shaping teeth. Individual shaping teeth are supported with respect to each of the reference surfaces to precisely locate shaping surfaces on the head of each of the teeth to form a plurality of intersecting rows of extrusion slots. The tubes form feed holes which discharge into a transition path at one end of the located shaping teeth. The transition path directs extrudable material from the feed section into the intersecting rows of extrusion slots to form a monolithic honeycombed structure with a high density cell pattern corresponding to the shape of the intersecting rows. The extrusion die is capable of extruding a ceramic monolith of 62 cells per square centimetre (400 cells per square inch). In one example, the shaping teeth have square heads, and the individual teeth are located on 0.127 centimetre (0.050 inch) centres located in a square pattern. The tube members are stainless steel tubes of 0.127 centimetre outer diameter (0.050 inch OD) with a wall thickness of 0.0051 centimetre (0.002 inch) (the resultant internal diameter (ID) equals 0.117 centimetre (0.046 inch)). The tube members can be any length. In this example, they preferably are 1.9 centimetre (0.750 inch) in length. If the tubes and teeth are connected by brazing, the parts
may be provided with an electrolytically-applied plating of copper, e.g., 0.00127 centimetre (0.0005 inch) thick.

The method more particularly includes loosely stacking tube members and fixing the shaping teeth to be accurately located one to the other before being joined to the loosely-stacked tubes to overcome inaccuracies in the location of the extrusion slot pattern and width of the cell walls which might otherwise result from variations in tube dimensions or alignment.

Specifically, in one such method, fixturing of the shaping teeth includes supporting the shaping teeth at their heads as, for example, by a grid formed by winding wire on spaced pins connected to and extending upwardly of a square hollow framework. The grid is used to accurately position the teeth as roots, i.e., shank portions, thereof are inserted into the loosely-stacked tube members. The tube and tooth members can be joined together by brazing or by adhesive bonding. If the tubes are to be adhesively bonded, a suitable curable adhesive material, e.g., epoxy resin adhesive material, can be applied to each tube as it is stacked. The characterizing feature of the method, however, is that the tubes are not rapidly bonded together before the teeth are inserted therebetween. Consequently, the teeth and tubes are aligned to precise dimensions established by the wire grid. Accordingly, the resultant extrusion-slot pattern of the extrusion die is precisely arranged prior to brazing or curing the component parts into a rigidly interconnected unitary die construction.
In one embodiment of the method, the shaping teeth are transferred as a unit by the wire grid and inserted into loosely-joined tube members which are then aligned with the shaping heads by referencing the wire grid with respect to a stacking block supporting the loose tubes. Thereafter, the tubes and shaping heads are joined together by suitable material such as brazing alloy or an epoxy resin material having a setting time that will enable the tubes to be positioned and aligned within the stacking block following insertion of the wire grid-located shaping teeth.

In another embodiment, the grid is located on a V-block and the individual shaping teeth are fixtured simultaneously with stacking the tubes in the V-block.

Other objects and advantages of the present invention will be more fully understood from a detailed description thereof when read with reference to the accompanying drawings, in which:

**Brief Description of the Drawings**

- Figure 1 is a perspective, exploded view of a portion of an extrusion die in accordance with the present invention;
- Figure 2 is a perspective view of a portion of the extrusion die of Figure 1 with the parts thereof joined;
- Figure 3 is an enlarged sectional view taken along the line 3-3 of Figure 4, looking in the direction of the arrows;
- Figures 4-6 are fragmentary end elevational views of extrusion dies with different head shapes and different feed hole patterns;
Figure 7 is a fragmentary view of a honeycomb structure formed by the extrusion die of the present invention as shown in Figures 1-3; Figure 8 is an enlarged fragmentary view of a single cell segment of the honeycomb structure shown in Figure 7; Figure 9 is a perspective view of a V-block used in one embodiment of the method of the present invention; Figure 10 is a perspective view of a wire grid fixture used in another embodiment of the method of the present invention; Figure 11 is an end elevational view of a tube stack in the V-block of Figure 9; Figure 12 is an enlarged fragmentary top elevational view of the wire grid fixture of Figure 10; and Figure 13 is an enlarged fragmentary side elevational view of the wire grid fixture with a shaping head therein.

Detailed Description of the Present Invention

Referring now to Figure 1 and Figure 2, a portion of a representative monolith extrusion die is depicted generally by reference numeral 10. It is seen as comprising a plurality of tube members 12 forming a feed section 14. The feed section is connected to a forming section 16 comprised of a plurality of shaping teeth 18 formed from cold-drawn wire having the desired shape as will be discussed.

More particularly, each of the tube members is a stainless steel tube having a length of 1.9 centimetre (0.750 inch), an OD of 0.127 centimetre...
(0.050 inch) and a wall thickness of 0.0051 centimetre (0.002 inch) (i.e., an ID of 0.117 centimetre (0.046 inch)). The teeth 18 are shown as having a square head 20 and a round shank 22. The shanks 22 are seated in interstices 24 formed between the tube members 12 as best shown in Figure 3. The interstices 24 are defined by tube wall segments 12a which form reference surfaces for the shanks 22 to accurately align the square heads 20 of the teeth 18 on preselected centres, which in the illustrated embodiment are on 0.127 centimetre (0.050 inch) centres located in a square pattern.

Each of the shaping teeth 18 also has an annular sloping surface 26 thereon which is located above the outlet end of each tube member 12. The sloping surfaces 26 form a transition path 28 for flow of extrusion material from feed hole 30 of each of the tube members 12 to extrusion slots which are formed by the square heads 20 as intersecting rows of extrusion slots 32, 34.

Additionally, the feed section 14 includes spacers in the form of wire pins 36 located between four of the tubes 12 at inlet end 38 thereof and engaged with an external wall segment 38a at each end. The wire pins 36 thereby maintain the tube members 12 in spaced parallelism with one another to define an array of reference interstices 24 which will accurately position the shaping teeth 18 with respect to the feed section 14. Accordingly, wet ceramic material directed through the feed section will be forced through precision-aligned extrusion slots 32, 34.
Each of the tubes 12, teeth 18 and pins 36 are coated with suitable bonding material, e.g., copper braze alloy or a suitable epoxy resin adhesive, which bonds the components together as a unitary extrusion die 10.

One feature of the present invention is that the use of separate tube members 12 and separate shaping teeth 18 enables the extrusion die 10 to be manufactured without time-consuming machining techniques. The above characterized extrusion die 10, when worn, can be replaced at relatively reduced cost because its individual parts are readily assembled by use of relatively low-cost components joined together by use of simplified tooling and assembling techniques.

One embodiment of the method of the present invention includes the steps of assembling a feed section 14 by stacking copper-plated tube members 12 in a V-block tool 40, e.g., a graphite block having two surfaces 42, 44 thereon arranged at right angle to one another, shown in Figures 9 and 11 (40' in Figure 11). The surfaces 42, 44 define a tube support guide which has an opening 45 at the top thereof and openings 46 at the ends thereof through which the tube members 12 and spacer pins 36 can be stacked in alignment with each other.

Specifically, the method includes a step-by-step stacking of the tube members 12 and spacer pins 36 into the tool 40 to form a tube and spacer stack 50. The illustrated stack 50 includes a first stack group 50a formed by tube 12d being placed at the apex 40a of the support tool 40.
Then, second and third tubes 12e, 12f are placed in the support tool 40 along with a spacer pin 36, and then a fourth tube 12g is added to complete the first stack group 50a. A second stack group 50b includes the addition of tubes 12h and 12i on either side of the tube 12g along with spacer pins 36 to form a third row of stacked tubes as viewed in Figure 11. The stack 50 is completed by stacking three more tubes 12j,k,l in the V-block tool 40 in a stack group 50c to complete a feed section 14 of square form. The tubes are self-centred one to the other as they are stacked. The illustrated stack 50 has the outmost tubes 12 arranged with their centre lines on the corners of a square. In one embodiment, the copper plating alloy material can be replaced by a coating of a curable adhesive material which will tend to stick the tubes together in their assembled position prior to bonding by the cured adhesive, e.g., epoxy resin adhesive material.

If brazing coatings are employed, the stack 50 prior to bonding must be carefully handled to prevent the upper tube members of the stack from rolling into a more stable triangular configuration represented by the first and second stack groups 50a and 50b. In fact, a temporary transient glue could be used to temporarily fix the tubes until brazing occurs.

The V-block support tool 40 and the braze alloy-coated version of the stack 50 are placed in a vacuum furnace and brazed with the copper plating serving as a brazing alloy to rigidly join the relatively supported and centred tube members 12.
The spacer pins 36 and line contacts 12m between each of the tubes 12 will produce accurately defined reference surfaces around each of the interstices 24 for receiving the shaping teeth 18.

If necessary, the opposite aligned ends 12b, 12c of the tubes in the tube stack 50 can be further finished to assure that the tube ends 12b, 12c will be parallel. Tubes can also be stacked to form a flat face by using a temporary backing plate (48 in Figure 11) and seating each tube back against the temporary plate. One suitable finishing step is to direct rotating non-contact machine heads, i.e., the electrode of an electrical discharge machining apparatus, to remove the ends of the tubes along a precision plane. Such finishing of the tube ends is preferred since it will produce desired burr-free parallel surfaces in the resultant unitary extrusion die for accurate placement in an extrusion assembly.

The copper-plated teeth 18 then have their shanks 22 inserted into the interstices 24 which serve to align the square heads 20 thereon to form the forming section 16. The assembled teeth 18 and the previously bonded feed section 14 are placed in a vacuum furnace and brazed to form the resultant extrusion die 10 of the present invention. If desired, the exposed end of the forming section can be further finished by machining the ends 20a thereof by use of a suitable finishing technique which will maintain the opposite end surfaces of the die in spaced parallelism to one another so that the die 10 will properly seat in associated extruding equipment. One such technique is use of a rotating electrode of
an electric discharge spark erosion machine which is
directed across the ends 20a to form a parallel
surface without forming burrs on the edges of the
shaping heads 18. Consequently, the intersecting
extrusion slots 32, 34 will have their exact
dimensional form preserved throughout the assembling
and finishing steps of the present invention.

The finished extrusion die 10 is then
placed in a suitable die holder with appropriate
masking to prevent damaging the precision shape of
the feed holes 30 or the extrusion slots 32, 34 prior
to extruding the extrudable material.

The importance of the precision assembling
method and resultant die construction of the present
invention is best understood when it is recognized
that the holes and slots form a ceramic monolith
substrate with a cell density of the order of 62
cells per square centimetre (400 cells per square
inch) and wall thicknesses of 0.015 centimetre
(0.006 inch). The resultant scale of such a monolith
is shown near scale in the fragmentary end section 60
shown in Figure 7. Figure 8 shows a blown-up section
60a of one of the cells. It has a wall thickness T
of 0.015 centimetre (0.006 inch) and an internal wall
dimension I of 0.112 centimetre (.044 inch) per side.
It is manifestly clear that such dimensional shapes
are only attained by use of precision die
constructions.

Use of the assembling methods of the
present invention enables precision dies to be
quickly formed by use of simple tooling and assembly
techniques rather than costly and laborious steps of
precision machining. Hence, the invention reduces the cost of initial tooling and the cost of replacement tooling requirements when tool life is reduced because of high throughput.

The apparatus formed by the aforesaid method can be formed from various shaping heads other than the illustrated square configuration. Also, various transition paths can be easily formed between the feed section and the forming section only by varying the pattern of the feed holes which direct extrudable material to the intersecting rows of extruding slots. Thus, as shown in the embodiment of Figures 1-4, the feed holes 30 are located with respect to square teeth so that the feed hole pattern includes a feed hole at each slot intersection. In Figure 5, the forming section is formed by use of shaping teeth 70 having triangular form. In the Figure 5 embodiment, feed holes 72 are located to accommodate a triangular-shaped tooth.

In Figure 6, the forming section is comprised of shaping teeth 80 having a hexagonal shape, and feed holes 82 therefor are located to accommodate such hexagonal-shaped teeth.

In each of the aforesaid embodiments, the different tooth shape will produce a different form of cell shape in the resultant monolith formed by the extrusion die. The cell shape change is easily accomplished merely by switching the shape of the tooth and the tube stacking sequence used in a particular design. If required, in all cases, at the end of the assembly process, any space remaining between the tubes and spacers (or the tubes if
spacers are omitted) may be filled with epoxy resin or other material so that the extrudable material flows only through the feed holes of the tubes for distribution through the desired distribution pattern into the extrusion slots for formation thereby into the finished monolith honeycomb shapes.

In another embodiment of the method of the present invention, tubes 12 are placed loosely in a V-block holder. The tubes are of the same form and material as in the first embodiment. However, if greater die strength is required, the length of the individual tubes can be increased. The tubes 12 are stacked loosely in the V-block holder 40' as described in the preceding embodiment. In this embodiment, the tubes 90 remain loosely stacked until shaping teeth 94 are precisely aligned one to the other by a fixture which will hold the teeth 94 in a fixed location. In the present case, teeth 94 are shaped as a pin having a square head portion 96, a transition land 97 and a round shank 98.

In this embodiment of the method of the present invention, the fixture for locating the teeth 94, as best seen in Figures 10 and 12, is in the form of a locator assembly fixture 100 having a hollow, square frame 102 having a plurality of spaced pins 104 secured thereto. Each of the pins 104 extends outwardly of the frame for defining reference points about which a wire grid 106 is wound. The wire grid 106 can be formed by wrapping a continuous wire around the pins 104 or can be formed by securing individual wires with the aid of a co-ordinate measuring machine.
The wire grid 106 has rows of openings 108 shown enlarged in Figure 12 which are located with respect to the tubes 90 by dowels 109 which connect between the square frame 102 and the V-block holder 40'. The shaping teeth 94 are then inserted one by one in the wire grid 106 to produce an exact pattern of the teeth 94 with precisely-formed intersecting rows 110, 112 of extrusion slots. The wire grid 106 assures the proper orientation of the square heads 96.

Once the tube and tooth structure has been built up to a desired size, it is either allowed to stand for curing of the epoxy resin adhesive or it is carefully placed in a brazing furnace including teeth, wire framework and tubes where the parts are joined into a unitary extrusion die like the die 10 of the first embodiment but with slightly differently-shaped teeth. If the assembly is brazed, a top portion 96a of each tooth 94 and the wire mesh 106 are removed from the assembly by suitable machining techniques, e.g., electrical discharge machining by spark erosion to expose the network of intersecting rows 110, 112 of extrusion slots.

The use of loosely-stacked tubes 90 enables the precisely-fixed shaping teeth 94 to centre and align each of the tubes 90 when the shanks 98 of the teeth 94 are located in the interstices 114 of the tube stack.

In another embodiment of the invention, the entire die including the tubes 90 and the teeth 94 are simultaneously placed on the V-block support 40'. In this case, the wire framework is located on
the tube-stacking V-block 40'. The teeth 94 are individually placed in a first row of cells 108a, and the shanks 98 of the teeth 94 are used as interstices spacers in place of spacer pins 111 as the individual tubes are stacked in a first row in the block 40'.

The wire framework 106 and the individual teeth guide the tubes 90 as alternate rows of teeth 94 are aligned with alternate rows of tubes until the die is fully built.

As in the other embodiments, any remaining space between the tubes may be filled with suitable plug material so that the extrudable material flows only through feed holes 115 in the tubes 90.

The practice of the present invention permits the economic manufacture of strong monolith extrusion dies which are readily built by use of individual components to avoid time-consuming machining techniques for forming small holes and slots in a solid steel plate. The assembly techniques result in high-strength extrusion dies capable of use under high extrusion pressures and capable of forming high-density, thin-walled honeycomb monoliths.
The claims defining the invention are as follows:

1. A method of making a die for extruding a body having a honeycomb structure, the die having a plurality of feed holes, an extrusion-slot pattern and a transition path for directing extrudant from the feed holes through the extrusion-slot pattern to form the shape of said honeycomb-structured body, said method comprising the steps of: stacking a plurality of individual tubes in spaced parallelism to one another to form a loose tube stack having a plurality of spaced parallel feed holes therein; providing a plurality of individual shaping teeth, each having a head portion and a shank portion; fixing each of said shaping teeth with respect to the other shaping teeth for providing accurate spacing between the head portions thereof for forming intersecting rows of extrusion slots; and inserting the shank portions of the fixed shaping teeth into said loose tube stack to produce accurate alignment of the shaping teeth with respect to the feed holes whilst conforming the intersecting rows of extrusion slots with the feed holes by adjusting the position of the loose individual tubes with respect to the fixed shaping teeth.

2. A method of making a die according to claim 1, in which the method includes bonding the individual shaping teeth and the loose tube stack together after the fixed teeth are located therein to form a unitary die having a precise extrusion-slot pattern fixed with respect to the feed holes.
3. A method of making a die according to claim 2, in which each of said shaping teeth are fixed together by use of removable retainer means which are bonded to the shaping teeth as the shaping teeth are bonded to the tube stack, and thereafter removing the retainer means from the shaping teeth with a portion of each of the shaping teeth to form an intersecting row pattern of the extrusion slots.

4. A method of making a die according to claim 2, in which the shaping teeth are fixed in a wire grid formed by wires extending across a framework.

5. A method of making a die according to claim 4, in which the wire grid is formed by winding a continuous length of wire around pins on the framework.

6. A method of making a die according to claim 1, in which the shaping teeth are simultaneously fixed to individual tube members whilst the individual tube members are stacked so that a portion of the shaping teeth will space the individual tubes at interstices therebetween.

7. A method of making a die according to claim 6, in which the shaping teeth are fixed in a wire grid formed by wires extending across a framework.

8. A method of making a die for extruding a body having a honeycomb structure substantially as hereinbefore particularly described, with reference to Figures 1 to 4 and 9 to 13 of the accompanying drawings.

DATED: 8 AUGUST 1990

GENERAL MOTORS CORPORATION
By their Patent Attorneys: PHILLIPS ORMONDE & FITZPATRICK