

METHOD AND APPARATUS FOR EXTRUSION INJECTION FORMING

Field of the Invention

- 5 This invention relates to a method and apparatus for extrusion injection forming and relates particularly, though not exclusively, to such a method and apparatus for forming ceramic articles.

10 Background of the Invention

Room temperature single/double screw extrusion is a continuous, commercial, fabricating process to produce ceramic tubes and other relatively large hollow sections. The starting raw materials are mixtures of ceramics powders and water-based binders. The mixtures are then formed into the required shape by extrusion. 15 The extruded parts are then oven or air dried prior to thermal debinding at 900 to 1000 °C. The debinded parts are then sintered at an elevated temperature of 1400 to 1700 °C.

- 20 Room temperature plunger extrusion is only used for batch ceramic tubes and other relatively large parts. The process is the same as for single/double screw extrusion with the exception of the shape forming process. In this process, the mixtures are first added to the extrusion chamber and then air is evacuated. After evacuation, the plunger pushes the materials out of the die to form the required shape. 25

However, the production yield is always low for high precision, relatively large and complex components. As a result, complex and costly secondary operations are required. All these make the process an expensive fabrication process, although 30 extrusion is considered one of the most inexpensive fabrication processes in terms of the "green" (prior to drying) part forming.

There is no commercialized high temperature ceramic extrusion process available that uses mixtures of powders and polymer binders.

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The latest commercialized high temperature ceramic extrusion is the use of a semi-solid high-temperature ceramic extrusion process. In this process, the starting raw

materials are mixtures of low melting glass with ceramics powders and the extrusion is conducted at a temperature over 600°C.

High temperature extrusion is available for aluminum and other metals and alloys.

- 5 The method is a batch process and the extrusion force is from a hydraulic plunger. The temperature is over 500°C.

- 10 Powder injection moulding utilizes the flow of the feedstock materials to form a complex shape via an injection moulding. The green parts are then debinded and sintered through particle diffusion process at high temperature.

The process is suitable for producing small metallic, ceramics and carbide materials with complex geometry in large volumes.

- 15 However, for products such as thin ceramic tubes, the manufacturing processes produce neither a high yield with a low cost nor the specific ceramic tube products.

Summary of the Invention

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- In accordance with a first preferred aspect there is provided apparatus for extrusion injection forming of an article in a cavity of a mould using a material, the apparatus comprising an extrusion head able to be operatively connected to the mould; the extrusion head comprising an inlet, an outlet passage operatively connected to the inlet and an outlet opening at an end of the outlet passage and remote from the inlet; the outlet passage being of a length and cross-sectional area for passage therealong of the material such that material flow is unidirectional, and for outlet of the material through the outlet opening with substantially uniform pressure over the cross-sectional area.

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The outlet opening may be of a cross-sectional area size and shape substantially corresponding to the cavity cross-sectional, area, size and shape.

- 35 According to a second preferred aspect there is provided apparatus for extrusion injection forming of an article in a cavity of a mould using a material, the apparatus comprising an extrusion head able to be operatively connected to the mould; the extrusion head comprising an inlet, an outlet passage operatively connected to the

inlet, and an outlet opening; the outlet passage being for passage therealong of the material; the outlet opening being of a cross-sectional area, size and shape substantially corresponding to the cavity cross-sectional area, size and shape.

- 5 According to a third preferred aspect there is provided a method for extrusion injection forming of an article in a cavity of a mould using a material, the method comprising:

(a) feeding the material into an extrusion head operatively connected to the mould; the extrusion head comprising an inlet, an outlet passage operatively
10 connected to the inlet; and an outlet opening at an end of the outlet passage and remote from the inlet;

(b) using an actuator to force the material into the outlet passage for passage therealong of the material such that material flow is unidirectional, and for
15 outlet of the material through the outlet opening with substantially uniform pressure over the cross-sectional area.

For all aspects the outlet passage may be of a cross-sectional area, size and shape the same as the outlet opening. The extrusion head may further comprise a hollow interior; the hollow interior comprising a pressure reservoir for the material
20 prior to the material entering the outlet passage. The extrusion head may be for injecting the material into the mould cavity for forming the article. There may be no nozzle at the outlet opening. The article may be of an aspect ratio in the range 1 to 500, preferably 1 to 300 (thickness to length). The article may be of a ceramics material, the material comprising at least one polymer binder and ceramic powders
25 to form a paste of a viscosity in the range 50 to 100 Pas⁻¹. The extrusion head may further comprises an actuator, the actuator being at least one of: a screw actuator, and a ram. The mould may be clamped using clamping plates. The clamping plates may be separate from the mould, or may be integral with the mould. The clamping plates may be able to move in a direction selected from: parallel to a longitudinal
30 axis of the cavity, perpendicular to the longitudinal axis of the cavity, and both parallel to the longitudinal axis of the cavity and perpendicular to the longitudinal axis of the cavity.

Brief Description of the Drawings

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In order that the present invention may be fully understood and readily put into practical effect, there shall now be described by way of non-limitative example only

preferred embodiments of the present invention, the description being with reference to the accompanying illustrative drawings.

In the drawings:

- 5 Figure 1 is perspective view of a first preferred embodiment;
Figure 2 is a vertical cross-sectional view along the lines of and in the direction of arrows 2-2 on Figure 1;
Figure 3 is a view corresponding to Figure 2 but of a second preferred embodiment;
10 Figure 4 is a view corresponding to Figure 2 but of a third preferred embodiment;
Figure 5 is a perspective view of a fourth preferred embodiment;
Figure 6 is a vertical cross-sectional view of the fourth preferred embodiment of Figure 5;
Figure 7 is perspective view of a product able to be produced using the
15 embodiments of Figures 1 to 6;
Figure 8 is a perspective view of a tube product able to be produced using the embodiments of Figures 1 to 6, or Figures 9 and 10;
Figure 9 is a perspective view of a preferred embodiment of a mould system for moulding the product of Figure 8; and
20 Figure 10 is a series of representations of the mould of Figure 9 showing the demoulding process using the extrusion injection moulding machine

Detailed Description of the Preferred Embodiments

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To refer to Figures 1 and 2, there is shown apparatus 10 for extrusion injection forming of an article (not shown). The apparatus 10 comprises a mould 12, a mould core 14, an extrusion head 16 and a material source generally indicated as 18.

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The mould 12 has a wall 20 and a cavity 22 sized and shaped to form the external shape and walls of the article to be formed. To form the internal shape of the article, the mould core 14 locates within the cavity 22 in the usual manner. The mould core 14 has a body 24 of the required length, size and shape; and a head 35 26 at the outer end of body 24 for locating against an end wall 28 of mould 12 when the mould core 14 is correctly located in cavity 22.

Lockers 30 are used during the mould process in the usual manner and serve to lock the mould core 14 into place during moulding.

5 The extrusion head 16 is provided to extrude and inject the material into the mould cavity 22. The extrusion head 16 has a body 32 with a hollow interior 34. The body 32 has an inlet opening 36 through which material is supplied by an actuator 38. In this case the actuator is a ram 48. The ram 48 may be one or more of: hydraulically, pneumatically, mechanically or electrically operated.

10 The body 32 also has an outlet passage 42 through which the material flows before entering the mould cavity 22. The outlet passage 42 ends at an outlet opening 44. The outlet opening 44 is substantially corresponding to and preferably of the same size, shape and cross-sectional area as the cavity 22 so that material flowing through outlet opening 44 will be of the necessary outer dimensions and shape
15 when entering cavity 22. This reduces stresses within the cavity 22, particularly on body 24.

The hollow interior 34 receives the material under pressure from the actuator 38. The hollow interior 34 has a portion 40 that is opposite or adjacent the outlet
20 passage 42. The portion 40 acts as a material cushion so that material enters the outlet passage 42 at relatively constant pressure, the portion 40 not only being a reservoir for material, but also effectively acting as a pressure buffer or reservoir. It is preferred for the portion 40 to extend so as to at least cover the full area of the opening into outlet passage 42. It is also preferred for the portion 40 to be tapered
25 (see Figures 5 and 6) so that the part of portion 40 adjacent hollow interior 34 is of a larger cross-sectional area, and the portion adjacent the outlet passage 42 is of reduced cross-sectional area. The reduced cross-sectional area should become that of the outlet passage 42, and the enlarged cross-sectional area adjacent the hollow interior 34 may be that same as that of the hollow interior 34.

30 As the material flows along outlet passage 42 to the outlet 44, the flow is unidirectional such that turbulence within the flow is minimized. This, plus the material in the portion 40, creates even pressure over the cross-sectional area of the outlet opening 44 so the flow of material into cavity 22 and over body 24 is
35 relatively even and smooth. This again assists in reducing stresses within cavity 22 particularly on body 24. The outlet passage 42 is aligned with cavity 22.

Figure 3 shows a second embodiment where the actuator 38 is a combination of a screw actuator 46 and a ram 48. As can be seen, the inlet 36 and the outlet passage 42 are axially aligned. Hence, the outlet passage 42 and the portion 40 are, essentially, integral. Furthermore, the cross-sectional area of the portion 40 is greater than the cross-sectional area of the cavity 22.

Figure 4 shows a third embodiment where the actuator is a screw actuator 46 that performs a metering function as well as an injection function. The material is supplied through the usual injection molding hopper (not shown). From there it is forced axially into the outlet passage 42 by the metering and injection actuator screw 46. Clamping plates 50 may be used for securing the mould 12. Alternatively, and as illustrated, the clamping plates 50 and the mould 12 are integrated so they are the same parts. Either or both of the clamping plates 50 may be moveable relative to the mould 12 (if they are separate parts) and the moulding barrel 16. The movement may be vertical (perpendicular to the longitudinal axis of the cavity 22) and/or horizontal (parallel to the longitudinal axis of the cavity 22). If the plates 50 and the mould 12 are the same parts the clamping may be by the two plates 50/12. They plates 50 may move in a direction perpendicular to the longitudinal axis of the mould core 14/mould cavity 22 and/or parallel to the longitudinal axis of the mould core 14/mould cavity 22. This embodiment is suitable for producing tubes with a length of 500mm or more.

Figures 5 and 6 show a preferred form of extruder head 16. The extruder head 16 is similar to that of Figures 1 to 4, except that the outlet passage 42 is longer. In this way there is a greater length of outlet passage for creating unidirectional and non-turbulent flow, with even pressure distribution over the cross-sectional area of the outlet passage 42. Again the outlet opening 44 is of the same cross-sectional area, size and shape as those of the cavity 22 and of the outlet passage 42.

Figure 7 shows an example of a product 52 produced using the embodiments of Figures 1 to 5 and is a ceramic tube that may be used in, for example, gas separation, microfiltration and nanofiltration.

Figure 8 shows a further product 54 and Figures 9 and 10 the mould system 56 for its formation. The product 54 is produced using a slightly modified form of the extruder head 16 described in relation to Figures 5 and 6. It is similar to the embodiment of Figures 5 and 6 but is different in size, and the forming machines

used. The mould system 56 [not shown in figures?] has the mould 12 and the mould core 14. Also provided are an ejector 58 and a fixed die 60. The ejector 58 has a protrusion 62 sized and shaped to reflect the height, thickness and shape of product 54. When moulding is concluded, the mould core 14 is removed (a) and the mould opens (b). The ejector 58 moves towards mould 12 and protrusion 62 enters mould 12 through an opening 64 and ejects the product 54 from mould 12 (c).

The extruder head 16 can be modified into other shapes as is shown in Figure 8. The sprue is equivalent to the hollow interior 34 in Figure 6, the runner is equivalent to the materials reservoir 42 in Figure 6, and the gate is equivalent to the outlet 44. The gate size may be the same size, or may be slightly smaller, in order to enhance the cavity life span.

When being used for ceramic products, the material will comprise a paste of pre-mixed material of ceramic materials, including metals, a binder such as a polymer binder, and liquid as required or desired. The powders and the binder mixing ratio follows the standard Powder Injection Moulding (PIM) feedstock, but it is preferred for the viscosity to be on the low side of the normal range of 50 to 120 Pas^{-1} -

Furthermore, the feedstock is preferably preheated to about 180°C, with the actual temperature depending on the polymer binders used. The mould 12 is also preferably heated to, for example, about 160°C to 170°C, with the mould 12 being heated as one zone. When moulding is complete, the mould 12 may be cooled by, for example, about 120-160°C to facilitate removal of the moulded product.

The products 52, 54 may have an aspect ratio (wall thickness to length of the tube) in the range 1 to 500, preferably 1 to 300. There is no limit on the width of the tube or product with the upper limit depending on the capacity of the machines used.

Whilst there has been described in the foregoing description preferred embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations or modifications in details of design or construction may be made without departing from the present invention.

THE CLAIMS

1. Apparatus for extrusion injection forming of an article in a cavity of a mould using a material, the apparatus comprising an extrusion head able to be operatively connected to the mould; the extrusion head comprising an inlet, an outlet passage operatively connected to the inlet and an outlet opening at an end of the outlet passage and remote from the inlet; the outlet passage being of a length and cross-sectional area for passage therealong of the material such that material flow is unidirectional, and for outlet of the material through the outlet opening with substantially uniform pressure over the cross-sectional area, wherein the article is of an aspect ratio (wall thickness to length of the tube) in the range 1:300 to 1:500.
2. Apparatus as claimed in claim 1, wherein the outlet opening is of a cross-sectional area size and shape substantially corresponding to the cavity cross-sectional, area, size and shape.
3. Apparatus for extrusion injection forming of an article in a cavity of a mould using a material, the apparatus comprising an extrusion head able to be operatively connected to the mould; the extrusion head comprising an inlet, an outlet passage operatively connected to the inlet, and an outlet opening; the outlet passage being for passage therealong of the material; the outlet opening being of a cross-sectional area, size and shape substantially corresponding to the cavity cross-sectional area, size and shape, wherein the article is of an aspect ratio (wall thickness to length of the tube) in the range 1:300 to 1:500.
4. Apparatus as claimed in claim 2 or claim 3, wherein the outlet passage is of a cross-sectional area, size and shape the same as the outlet opening.
5. Apparatus as claimed in any one of claims 1 to 4, wherein the extrusion head further comprises a hollow interior; the hollow interior comprising a pressure reservoir for the material prior to the material entering the outlet passage.
6. Apparatus as claimed in any one of claims 1 to 5, wherein the extrusion head is for injecting the material into the mould cavity for forming the article.
7. Apparatus as claimed in any one of claims 1 to 6, wherein the article is of a ceramics material, the material comprising at least one polymer binder and powders for forming the ceramics material, to form a paste of a viscosity in the range 50 to 100 Pas⁻¹.

8. Apparatus as claimed in any one of claims 1 to 7, wherein the extrusion head further comprises an actuator, the actuator being at least one selected from the group consisting of: a screw actuator, and a ram.
9. Apparatus as claimed in claim 8, wherein the actuator is for performing a metering function as well as an injection function.
10. Apparatus as claimed in any one of claims 1 to 9, wherein the mould is clamped using clamping plates.
11. Apparatus as claimed in claim 10, wherein the clamping plates are separate from the mould.
12. Apparatus as claimed in claim 10, wherein the clamping plates are integral with the mould.
13. Apparatus as claimed in any one of claims 10 to 12, wherein the clamping plates are able to move in a direction selected from the group consisting of: parallel to a longitudinal axis of the cavity, and perpendicular to the longitudinal axis of the cavity.
14. A method for extrusion injection forming of an article in a cavity of a mould using a material, the method comprising:
 - (a) feeding the material into an extrusion head operatively connected to the mould; the extrusion head comprising an inlet, an outlet passage operatively connected to the inlet; and an outlet opening at an end of the outlet passage and remote from the inlet;
 - (b) using an actuator to force the material into the outlet passage for passage therealong of the material such that material flow is unidirectional, and for outlet of the material through the outlet opening with substantially uniform pressure over the cross-sectional area of the outlet passage,
wherein the article is of an aspect ratio (wall thickness to length of the tube) in the range 1:300 to 1:500.
15. A method as claimed in claim 14, wherein the outlet opening is of a cross-sectional area size and shape substantially corresponding to the cavity cross-sectional area size and shape.
16. A method as claimed in claim 14 or 15, wherein the outlet passage is of a cross-sectional area, size and shape the same as the outlet opening.

17. A method as claimed in any one of claims 14 to 16, further comprising providing in the extrusion head a pressure reservoir for the material prior to the material entering the outlet passage.
18. A method as claimed in any one of claims 14 to 17, wherein the material is injected into the mould cavity by the extrusion head.
19. A method as claimed in any one of claims 14 to 18, wherein the mould is clamped using clamping plates.
20. A method as claimed in claim 19, wherein the clamping plates are separate from the mould.
21. A method as claimed in claim 19, wherein the clamping plates are integral with the mould.
22. A method as claimed in any one of claims 19 to 21, wherein the clamping plates are able to move in a direction selected from the group consisting of: parallel to a longitudinal axis of the cavity, perpendicular to the longitudinal axis of the cavity, and both parallel to the longitudinal axis of the cavity and perpendicular to the longitudinal axis of the cavity.