FOAMED PLASTICS MATERIAL PROCESSING

Abstract: Foamed plastics material processing apparatus and method. A conventional screw extruder (12) is provided leading to a cavity transfer mixer (18). Chilled carbon dioxide is injected into the mixer (18) to mix with the plastics material as a liquid and remain so until passing out through a die (78) where foaming takes place.
FOAMED PLASTICS MATERIAL PROCESSING

This invention concerns foamed plastics material processing apparatus and method; foam extrusion apparatus and a method of foam extrusion; and an injection moulding apparatus and method of injection moulding foamed plastics material.

In extruding items of foamed plastics material, a plastics material is extruded under pressure with gas in solution in the material. As the material passes out of the die and hence the pressure decreases, the gas passes out of solution causing foaming to occur. Some of the gases conventionally used in this process are considered to be ecologically unfriendly and therefore different gases have been sought. Such different gases are generally less soluble and therefore require greater pressures to permit sufficient gas to be dissolved. For these and other foaming agents the molten polymer/gas solution must have sufficient strength during expansion at the die exit to prevent bubbles bursting and coalescing and hence decreasing foaming action.

Melt strength is increased by cooling the molten polymer before it enters the die. The cooled polymer remains fluid as a result of the dissolved gas plasticising the molten polymer. The mixing of these fluids into polymers is normally carried out using dynamic mixers as part of the extruder screw. These tend to raise the temperature of the molten polymer as a result of the rotating mixing device mechanically generating shear heat.

The term "cavity transfer mixer" when used hereinafter, is to be understood as meaning a mixer along the length of which material travels. The mixer comprises a stator in which a rotor rotatably locates. Cavities are provided on the outside surface of the rotor and the inside surface of the stator. For material to travel along the mixer, the material substantially requires to transfer between cavities on the stator and rotor, and vice versa. During the transfer between the cavities, thorough mixing of material occurs, and particularly as from any one cavity material will transfer to a number of other
cavities. An example of such a mixer is described in the Applicants' European Patent No. 0463759.

The term "static mixer" when used hereinafter is to be understood as meaning a mixer along the length of which material travels. The mixer comprises means defining a passage along which material passes, and an insert in the passage. The insert is such as to cause material passing through the passage to be divided and moved laterally.

According to the present invention there is provided plastic materials processing apparatus, the apparatus comprising a screw extruder into which thermoplastics material can be fed, with the outlet of the screw extruder connecting with the inlet of a cavity transfer mixer into which a volatile fluid can be injected under pressure to mix with the thermoplastics material, the cavity transfer mixer being arranged such that material exiting therefrom passes to a forming stage under pressure, the apparatus also comprising means for controlling the temperature of the cavity transfer mixer whereby to cool, but not solidify, the thermoplastics material therein.

The temperature controlling means may comprise means for bringing a control fluid into contact with the cavity transfer mixer. The control fluid may be an oil. The control fluid may be brought into contact with the rotor and/or stator of the cavity transfer mixer. The cavity transfer mixer may be arranged such that the control fluid is brought into contact with an outer surface of the stator, and desirably within a jacket. The cavity transfer mixer may be arranged such that the control fluid is brought into contact with the hollow interior of the rotor.

The temperature control means may be arranged to recirculate the control fluid, with the fluid being brought to a required temperature prior to return to the cavity transfer mixer.

The temperature controlling means preferably comprises means for
cooling and/or means for warming the control fluid.

The apparatus may comprise means for injecting liquid carbon dioxide into the cavity transfer mixer. The injecting means may comprise a piston pump or gear pump, and may comprise means for cooling the carbon dioxide prior to injection.

The forming stage may comprise a die for foam extrusion, or may comprise an injection moulding assembly.

The apparatus may also comprise a static mixer located immediately downstream of the cavity transfer mixer. Means are preferably provided for controlling the temperature of the static mixer whereby to cool, but not solidify, the thermoplastics material therein. The static mixer may be arranged such that the control fluid is brought into contact with the exterior of the static mixer, and desirably within a jacket.

The temperature controlling means for the static mixer may be common with that of the cavity transfer mixer. The apparatus may be arranged such that control fluid from the cavity transfer mixer subsequently passes to the static mixer or vice versa, prior to recirculating.

The cavity transfer mixer and screw extruder may have a common drive.

The invention also provides foam extrusion apparatus, the apparatus being according to any of the preceding nine paragraphs.

The invention further provides injection moulding apparatus for foamed plastics materials, the apparatus being according to any of said preceding nine paragraphs.

The invention also provides a method of processing foamed plastics material, the method comprising feeding a thermoplastics material into a screw
extruder, extruding the material into a cavity transfer mixer, injecting liquid carbon dioxide under pressure into the cavity transfer mixer, following mixing of the carbon dioxide and thermoplastics material in the cavity transfer mixer passing the mixture through a forming stage to cause foaming, with the temperature of the cavity transfer mixer being controlled during the process to provide cooling, but not solidifying, of the thermoplastics material therein.

The carbon dioxide may be cooled prior to injection, and preferably to around 0°C.

The thermoplastics material and carbon dioxide mixture may be passed into a static mixer before passing into the die, and the temperature of the static mixer may be controlled to provide cooling, but not solidifying, of the thermoplastics material therein.

The thermoplastics material may be any of polystyrene, polyethylene, polypropylene, polyether ether ketone, polyethylene terephthalate, polyphenylene oxide-modified, or styrene maleic anhydride terpolymer.

The temperature of the cavity transfer mixer and/or static mixer may be controlled by bringing a fluid into contact therewith. The fluid may be recirculated. The fluid may be brought into contact with the cavity transfer mixer and/or static mixer at a temperature in the range 100-120°C or as appropriate for the type of polymer being formed.

The forming stage may comprise an extrusion die, or may comprise an injection moulding assembly.

The invention also provides a method of extruding foamed plastics material, the method being according to any of the preceding six paragraphs.

The invention yet further provides a method of injection moulding foamed plastics material, the method being according to any of said preceding
six paragraphs.

Embodiments of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Fig. 1 is a diagrammatic side view of a first extrusion apparatus according to the invention;

Fig. 2 is a diagrammatic cross-sectional view through part of the apparatus of Fig. 1;

Fig. 3 is a cross-sectional view through part of a component of Fig. 2;

Fig. 4 is a diagrammatic cross-sectional view of a second extrusion apparatus according to the invention;

Figs. 5 and 6 are respectively diagrammatic cross-sectional views of a first injection moulding apparatus according to the invention, in first and second conditions; and

Fig. 7 is a diagrammatic cross-sectional view of a second injection moulding apparatus according to the invention.

Fig 1 to 3 of the drawings show foam extrusion apparatus 10 suitable for extruding a large range of thermoplastics materials such as for example polystyrene, polyethylene or polypropylene, or higher temperature materials, including high melting engineering plastics materials. The apparatus comprises a conventional screw extruder 12 with a screw conventional for unfoamed extrusion, with a feed hopper 14 at its inlet end 16. A cavity transfer mixer 18 coaxially extends from the outlet end 20 of the extruder 12. A common drive 22 is provided for the extruder 12 and mixer 18.

The mixer 18 is shown in most detail in Fig. 2 and comprises a hollow
rotor 24 rotatably mounted with minimal clearance in a stator 26. A plurality of hemispherical cavities 28 are provided on the outer surface of the rotor 24 and the inner surface of the stator 26. The cavities 28 on the rotor 24 are offset, relative to the cavities 28 on the stator 26 but partially overlie these cavities 28, such that material passes through the mixer 18, i.e. to the left as shown in Fig. 2, by passing respectively from a cavity 28 on a stator 26 into a cavity 28 on the rotor 24 and back into a further cavity 28 on the stator 26 and so on.

A gas injection arrangement 30 is provided connected to adjacent the inlet end 32 of the mixer 18. The arrangement 30 comprises a cylinder 34 of carbon dioxide which connects via a pump 36 and flow meter 38 through a non-return poppet valve 40 into the mixer 18 opposite a part of the rotor 24 of reduced diameter. A chiller 42 is provided to ensure that the carbon dioxide enters the mixer 18 as a chilled liquid, typically at a temperature of around 0°C. A temperature and pressure sensor 44 is provided extending into the mixer 18 diametrically opposite the valve 40.

A static mixer 46 is mounted on the downstream end of the cavity transfer mixer 18. The mixer 46 comprises a hollow body 48 defining a passage 50 through which the mixed thermoplastics material and gas can pass. An insert 52 is provided within the passage 50 to cause the thermoplastics material and gas mixture to be divided and moved laterally within the passage 50. A cross-sectional view of an insert 52 is shown in Fig. 3, but other configurations commonly used in extrusions may be used.

A temperature control arrangement 54 is provided for the cavity transfer mixer 18 and static mixer 46. The arrangement 54 comprises a temperature controller 56 which provides oil to an outlet pipe 58 at a required temperature. The outlet pipe 58 feeds the oil which in most instances is likely to be at a temperature of around 100-120°C, into a jacket 66 around the outside of the stator 26 through an inlet 60 and the oil eventually passes out through an outlet 62.
Oil also passes through a tube 64 into the hollow centre of the rotor 24, and returns around the outside of the tube 64. A generally similar jacket 68 is provided around the static mixer 46 and has an inlet 70 which receives oil from the cavity transfer mixer outlet 62. The jacket 68 has an outlet 72 from which oil is returned by a pipe 74 to the temperature controller 56. A temperature and pressure sensor may be provided at the inlet end of the static mixer 46.

Downstream of the static mixer 46 is a die 78. Downstream of the die 78 is a calibrator 80 with a through passage of a required shape to provide a desired profile for the foamed plastics material formed. The calibrator 80 has a water cooled jacket 82. A haul-off 84 is provided downstream of the calibrator 80 to pull the finished material 86 through, by virtue of rollers and tracks 88.

In use, a thermoplastics material such as polystyrene, polyethylene or polypropylene, or other plastics material, is fed in pellet form through the hopper 14 into the extruder 12 where it is melted and mixed as is conventional. The molten plastics material passes into the cavity transfer mixer 18 around the rotor 24. Liquid carbon dioxide at around 0°C is injected at this point at a pressure greater than that of the polymer melt, and the cavity transfer mixer 18 ensures thorough mixing.

Heat is produced in the mixer 18 due to the shearing of the plastics material. Heat is taken from the mixer 18 by the circulating oil. The oil is fed in at an appropriate temperature for the particular plastics material, with the temperature being chosen to cool the plastics material, but avoid any solidifying thereof. The continual transfer of material back and forth between stator and rotor exposes all the material to large cooling surfaces. The carbon dioxide and plastics material mixture then passes into the static mixer 46 for further cooling which is provided by the recirculated oil. The mixture then passes into the die and as it leaves the die and the pressure reduces, foaming takes place. The still warm material is passed through the calibrator for shaping, and the cooling in the calibrator stabilises the material below the plastics material softening point.
Fig. 4 shows an alternative apparatus 90 in which the cavity transfer mixer 18, static mixer 46 and die 78 are a separate assembly with their own drive motor 92. This enables the mixer to be independent of the extruder. At lower speeds less heat will be generated and cooling needs will be reduced.

There are thus described extrusion apparatus which provide for considerable advantages relative to existing arrangements. The apparatus is of relatively conventional construction and can thus be inexpensively and robustly manufactured. The invention also provides a method of extrusion. Cooling the carbon dioxide permits it to be pumped as a liquid at lower pressures than otherwise would be the case. The cavity transfer mixer provides for very thorough mixing with a high surface area of the mixer in contact with the thermoplastics material, to promote cooling. The apparatus is usable with a wide range of materials, with appropriate parameters and especially working temperatures and pressures selected for particular materials. The main requirement for a thermoplastics material to be suitable is that it has a melt strength sufficiently high for foaming.

With the temperature control of the cavity transfer mixer this provides for close control of the material. Providing for temperature control of the actual cavity transfer mixer allows the significant heat build-up due to the high amount of shearing to be countered quite rapidly. The present apparatus performs the required mixing and cooling whilst enabling lower gas injection pressure than is often the case. This permits the apparatus to be used with a higher die pressure whilst accommodating a less soluble gas such as carbon dioxide.

The injection of the carbon dioxide into the cavity transfer mixer enables a conventional screw extruder arrangement to be used. The common drive of the extruder and cavity transfer mixer reduces the cost of the apparatus and also readily allows the apparatus to be retrofitted to existing systems. The invention is usable with a wide range of thermoplastics material, with the oil temperature being selected to suit the particular material.
Whilst the above described example relates to foam extrusion, the invention is readily usable with injection moulding of foamed plastics materials, examples of which are shown in Figs 5 - 7.

Figs. 5 and 6 show an injection moulding apparatus 100. The apparatus 100 comprises an extruder 12, cavity transfer mixer 18 and static mixer 46 as described above. The mixer 46 leads to a valve 102, which permits in a first condition as shown in Fig. 5 plastics material to enter the barrel 104 of an injection moulding piston 106. In a second condition as shown in Fig. 6, once the barrel 104 has been filled, the valve 102 switches such that material can be injected from the barrel 104 through a die 108 to foam. The extruder 12 could be arranged to slow down or stop during injection, or each extruder 12 could feed a plurality of injection arrangements.

Fig. 7 shows a further injection moulding apparatus 110. In this instance the extruder 12 and cavity transfer mixer 18 are in line, and are movable relative to a barrel 112 by a piston 114 to inject material through a die 116.

Instead of using a piston in an injection moulding arrangement, a screw could be used to provide the injection. This may require providing plastics material with and without carbon dioxide in different parts of the screw to retain the carbon dioxide mixed with the plastics material.

Various other modifications may be made without departing from the scope of the invention. For example, a different static mixer may be used, and the insert may have a different geometry. In some circumstances the static mixer may have a separate cooling arrangement, or may not require a cooling arrangement. In other circumstances it may be possible to manage without a static mixer.

Whilst endeavouring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should
be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.
CLAIMS

1. Plastics materials processing apparatus, the apparatus comprising a screw extruder into which thermoplastics material can be fed, with the outlet of the screw extruder connecting with the inlet of a cavity transfer mixer into which a volatile fluid can be injected under pressure to mix with the thermoplastics material, the cavity transfer mixer being arranged such that material exiting therefrom passes to a forming stage under pressure, the apparatus also comprising means for controlling the temperature of the cavity transfer mixer whereby to cool, but not solidify, the thermoplastics material therein.

2. Apparatus according to claim 1, characterised in that the temperature controlling means comprises means for bringing a control fluid into contact with the cavity transfer mixer.

3. Apparatus according to claim 2, characterised in that the control fluid is an oil.

4. Apparatus according to claims 2 or 3, characterised in that the control fluid is brought into contact with the rotor and/or stator of the cavity transfer mixer.

5. Apparatus according to any of claims 2 to 4, characterised in that the cavity transfer mixer is arranged such that the control fluid is brought into contact with an outer surface of the stator, and desirably within a jacket.

6. Apparatus according to any of claims 2 to 5, characterised in that the cavity transfer mixer is arranged such that the control fluid is brought into contact with the hollow interior of the rotor.

7. Apparatus according to any of claims 2 to 6, characterised in that the cavity transfer mixer is arranged such that the control fluid is brought into
contact with the hollow interior of the rotor.

8. Apparatus according to any of claims 2 to 7, characterised in that the temperature controlling means comprises means for cooling and/or means for warming the control fluid.

9. Apparatus according to any of the preceding claims, characterised in that the apparatus comprises means for injecting liquid carbon dioxide into the cavity transfer mixer.

10. Apparatus according to claim 9, characterised in that the injecting means comprises a piston pump or gear pump.

11. Apparatus according to claims 9 or 10, characterised in that the injecting means comprises means for cooling the carbon dioxide prior to injection.

12. Apparatus according to any of the preceding claims, characterised in that the apparatus also comprises a static mixer located immediately downstream of the cavity transfer mixer.

13. Apparatus according to claim 12, characterised in that means are provided for controlling the temperature of the static mixer whereby to cool, but not solidify, the thermoplastics material therein.

14. Apparatus according to claims 12 or 13 when dependent on claim 2, characterised in that the static mixer is arranged such that the control fluid is brought into contact with the exterior of the static mixer, and desirably within a jacket.

15. Apparatus according to claim 13 or claim 14 when dependent on claim 13, characterised in that the temperature controlling means for the static mixer is common with that of the cavity transfer mixer.
16. Apparatus according to claim 15, characterised in that the apparatus is arranged such that control fluid from the cavity transfer mixer subsequently passes to the static mixer or vice versa, prior to recirculating.

17. Apparatus according to any of claims 12 to 16, characterised in that the cavity transfer mixer and screw extruder have a common drive.

18. Apparatus according to any of the preceding claims, characterised in that the forming stage comprises a die for foam extrusion.

19. Apparatus according to any of claims 1 to 17, characterised in that the forming stage comprises an injection moulding assembly.

20. Foam extruding apparatus, the apparatus being according to claim 18.

21. Injection moulding apparatus for foamed plastics materials, the apparatus being according to claim 19.

22. A method of processing foam plastics material, the method comprising feeding a thermoplastics material into a screw extruder, extruding the material into a cavity transfer mixer, injecting liquid carbon dioxide under pressure into the cavity transfer mixer, following mixing of the carbon dioxide and thermoplastics material in the cavity transfer mixer passing the mixture through a forming stage to cause foaming, with the temperature of the cavity transfer mixer being controlled during the process to provide cooling, but not solidifying, of the thermoplastics material therein.

23. A method according to claim 22, characterised in that the carbon dioxide is cooled prior to injection, and preferably to around 0°C.

24. A method according to claims 22 or 23, characterised in that the thermoplastics material and carbon dioxide mixture are passed into a static
mischer before passing into the die.

25. A method according to claim 24, characterised in that the temperature of the static mixer is controlled to provide cooling, but not solidifying, of the thermoplastics material therein.

26. A method according to any of claims 22 to 25, characterised in that the thermoplastics material is any of polystyrene, polyethylene, polypropylene, polyether ether ketone, polyethylene terephthalate, polyphenylene oxide-modified, or styrene maleic anhydride terpolymer.

27. A method according to any of claims 22 to 26, characterised in that the temperature of the cavity transfer mixer and/or static mixer is controlled by bringing a fluid into contact therewith.

28. A method according to claim 27, characterised in that the fluid is recirculated.

29. A method according to claims 27 or 28, characterised in that the fluid is brought into contact with the cavity transfer mixer and/or static mixer at a temperature in the range 100-120°C, or as appropriate for the type of polymer being formed.

30. A method according to any of claims 22 to 29, characterised in that the forming stage comprises an extruding die.

31. A method according to any of claims 22 to 29, characterised in that the forming stage comprises an injection moulding assembly.

32. A method of extruding foamed plastics material, the method being according to claim 30.

33. A method of injection moulding foamed plastics material, the method
being according to claim 31.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B29C44/34

According to International Patent Classification (IPC) or to both national classification and IPC.

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B29C

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

Special categories of cited documents:
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Document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

Current document member of the same patent family

Date of the actual completion of the international search
8 March 2001

Date of mailing of the international search report
16/03/2001

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