Title: LOW SHEAR PELLETIZATION METHOD AND APPARATUS THEREFOR

Abstract: A method of pelletizing material is disclosed which includes the steps of placing a material into an extruder having an screw, a discharge end, and a die having at least one opening at its discharge end. The screw is actuated to move the material toward the discharge end and through the at least one opening in the die while being heated as it travels toward the discharge end. In this manner, the material is at least partially melted while the temperature of the material is prevented from reaching a compounding temperature. The material is cut into pellets after it passes through the at least one opening in the die. An extruder for carrying out the above method and a resulting product are also disclosed.
LOW SHEAR PELLETIZATION METHOD AND APPARATUS THEREFOR

FIELD OF THE INVENTION

The present application is directed toward a method and apparatus for pelletizing a polymeric material, and the pelleted polymeric material thus formed, and, more specifically, toward a method and apparatus for forming a powdered polymeric material into pellets through minimal energy input without adversely affecting the suitability of the pelleted material for further processing, such as melt processing, and without adversely affecting physical properties of the material.

BACKGROUND OF THE INVENTION

Decreasing landfill space and rapidly rising disposal costs have forced many municipalities to begin curbside recycling of post-consumer plastic (polymeric) waste. The amount of plastic collected by such programs is huge. For example, the American Plastics Council reports that, in the year 2000, the weight of plastic bottles alone in the collected material was over 1.5 billion pounds. Such waste includes significant quantities of polyethylene (PE), including low density polyethylene (LDPE) (which may include linear low density polyethylene (LLDPE)) and high density polyethylene (HDPE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), polyethylene terephthalate (PET) and polyurethane. Other types of plastic are also often present in varying amounts.

Currently, collection of plastic waste material exceeds the market demand for recycled plastic products. This is because it is difficult to produce high quality plastic products from recycled materials at a reasonable cost. One recycling approach involves the batch grinding of commingled, unsorted mixed color plastic waste to form flake scrap
material, melt processing and pelletizing the melt processed material, and extruding the pelletized plastic waste to form recycled plastic products. However, recycled plastic products made in this manner suffer from severe deficiencies that render the products unsatisfactory for many purposes and are inferior to products made from virgin polymeric materials. For example, these recycled plastic products exhibit inferior mechanical properties (e.g. tensile, flexural and impact strength) and inferior appearance in terms of color (dark brown or gray color) with streaking of colors within the molded product as a result of the chemical incompatibility of the different polymers present in the initial plastic waste stream and variations in the plastic waste stream composition over time.

The most common recycling approach involves sorting commingled, post-consumer plastic scrap to overcome the polymer incompatibility problems associated with the recycling of commingled plastic scrap. Sorting can be costly and require the use of video cameras, infrared detectors, and organic "markers" to segregate like plastics. However, even sorted plastic waste can present problems in processing as a result of density and chemical differences among polymers falling in the same general class and polymers made by different plastics manufacturers.

A solution to this problem, which avoids the need for expensive sorting, is offered by the process of solid state shear pulverization (SSSP), which process makes polymeric particulates (e.g. powder) from sorted or unsorted, commingled polymeric scrap material, virgin polymeric material and mixtures thereof. In this process, waste material is fed to an extruder screw that rotates to transport the material along its length and, in the solid state, convert the material to a pulverized powder that is melt processable directly by conventional blow molding, rotational molding, pipe extrusion, spray coating and other melt processing techniques requiring a powder feedstock. Particulates produced in this manner do not suffer from the drawbacks of prior art flake scrap material, even when the input comprises unsorted wastes that include incompatible polymers. The SSSP process is described in detail in U.S. Patent No. 6,180,685 and U.S. Patent No. 5,814,673, which patents are hereby incorporated by reference.

While the SSSP process is economical and provides a useful powder having many desirable properties, many injection molding machines and extruders require a pelletized input rather than a powdered input. Even powder compacted into briquettes is not
completely satisfactory. This is partly due to the bridging that occurs when powder is
fed into the hoppers of these machines. A significant market for the material produced by
the SSSP process therefore remains untapped because the powdered material is not being
used for injection molding and extruding (excluding pipe extrusion).

It is possible to pelletize the material formed by the SSSP process in a
conventional compounding extruder, such as extruder E shown in Figure 7. Extruder E
comprises a barrel 200 having an input opening 202 at a first end 204 and a die 206,
having at least one opening 208, mounted at an output end 210. A screw 212 is mounted
for rotation within barrel 200, which screw 212 comprises a plurality of interconnected
segments that include flighted segments 214 and compounding segments 216 having
kneading blocks 218. A powdered material (not shown) is placed into barrel 200 through
input opening 202 and is moved toward a first group 220 of compounding segments 216
by the rotation of screw 212. The material is heated, such as through the use of resistive
heating elements (not shown), mounted on the exterior of barrel 200, as it moves through
barrel 200 toward output end 208. Kneading blocks 218 shear the material as it passes
and help to further heat and mix the material. After passing through a second group 222
of kneading blocks, which further shear the material, the powdered material has been
converted to a substantially homogeneous, flowable material that can be extruded and cut
into pellets that can be used for injection molding. Unfortunately, when a powder
produced by solid state shear pulverization is used as the input material for such a
conventional pelletizer, the heat and shear forces introduced during processing adversely
affect the properties and characteristics of the material, and lead to the production of
pellets having degraded properties that may not be well-suited for use as input for
injection molding or extrusion.

It is therefore desirable to provide a method and apparatus for forming polymeric
materials, especially those produced by the solid state shear pulverization process, into
pellets, which pellets have chemical and physical properties that make them suitable for
use as input materials for injection molding machines and extruders.

SUMMARY OF THE INVENTION

These problems and others are addressed by the present invention which
comprises, in a first aspect, a method of pelletizing material that involves placing a material into an extruder which has at least one screw, a discharge end, and a die having at least one opening at the discharge end, and actuating the at least one screw to move the material toward the discharge end and through the opening in the die. The material is heated in a controlled manner as it travels toward the discharge end and at least partially melted, while at the same time the temperature of the material is prevented from reaching a compounding temperature. The material may be cut into pellets after it passes through the opening in the die.

Another aspect of the invention involves a method of pelletizing material that involves applying sufficient energy to the material to change a physical property of the material without changing the chemical composition of the material, extruding the material, and forming the extruded material into pellets.

A further aspect of the invention comprises a method of pelletizing material that involves providing an extruder having a screw with at least one flight and no kneading blocks, a discharge end, and a die having at least one opening at the discharge end. Material is placed into the extruder and heated, and the extruder screw is rotated to move the material toward the discharge end and through the opening in the die. The material is then cut into pellets.

Another aspect of the invention comprises pelletized material produced from a compatibilized mixture of at least two non-compatible plastics formed by solid state shear pulverization. The material is added to an extruder having a screw, a discharge end, and a die having at least one opening at the discharge end, and the screw is actuated to move the material toward the discharge end and through the at least one opening in the die. The temperature of the material is controlled as it travels toward the discharge end to at least partially melt the material, while preventing the temperature of the material from reaching a compounding temperature. The material is cut into pellets after it passes through the die.

A further aspect of the invention comprises a pelletizer having a barrel with a discharge end and a screw having a constant diameter, and at least one flight and no kneading blocks that is mounted for rotation in the barrel. A die having at least one opening is mounted at the discharge end of the barrel, and a cutter is provided for cutting
material exiting the die into pellets.

Also disclosed is a method of pelletizing material with an extruder having a constant diameter screw with at least one flight and no elements adapted to impart a shearing force to the material in the extruder. The extruder has a discharge end, and a die having at least one opening is mounted at the discharge end. Material is placed into the extruder, and the extruder screw is rotated to move the material toward the discharge end and through the at least one opening in the die, after which the material is cut into pellets.

Another aspect of the invention comprises a method of processing a powdered material using an extruder having a screw, a discharge end, and a die having at least one opening at the discharge end. The material is placed into the extruder, and the screw is rotated to move the powdered material toward the discharge end and through the at least one opening in the die. The material is heated as it travels toward the discharge end and at least partially melted without changing the chemical composition thereof.

A further aspect of the invention comprises a method of pelletizing a blend of powdered polyolefin material produced by solid state shear pulverization using an extruder having a fixed-diameter screw, a discharge end, three zones and a die having at least one opening at the discharge end. The material is placed into the extruder and the screw is rotated to move the material through the three zones toward the discharge end and through the at least one opening in the die. While in the extruder, the temperature of the material in each of the zones is controlled independently, and the material is cut into pellets after it passes through the at least one opening in the die.

An additional aspect of the invention comprises a method of pelletizing solid state shear pulverized linear low density polyethylene (LLDPE) material in an extruder having a fixed-diameter screw, a discharge end, three zones and a die having at least one opening at the discharge end. The LLDPE material is placed into an extruder, and the extruder screw is rotated rotating to move the LLDPE material through the zones toward the discharge end and through the at least one opening in the die. The temperature of the LLDPE material in each zone is independently controlled, and the LLDPE material is cut into pellets after it passes through the at least one opening in the die.

A further aspect of the invention comprises a method of pelletizing solid state shear pulverized high density polyethylene (HDPE) material in an extruder having a
fixed-diameter screw, a discharge end, three zones and a die having at least one opening at the discharge end. The HDPE material is placed into an extruder, and the extruder screw is rotated to move the HDPE material through the zones toward the discharge end and through the at least one opening in the die. The temperature of the HDPE material in each zone is independently controlled, and the HDPE material is cut into pellets after it passes through the at least one opening in the die.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention will become apparent from a reading and understanding of the detailed description of the invention together with the following drawings.

Figure 1 is a broken away side elevational view of a device for pelletizing powdered polymeric material according to the present invention.

Figure 2 is a sectional view taken along line 2-2 of Figure 1.

Figure 3 is a table showing the properties of two virgin LLDPE blends when the blends are subjected to different processes.

Figure 4 is a table showing the properties of a recycled five-component blend of polymeric materials when the blend of materials is subjected to different processes.

Figure 5 is a table showing the properties of two virgin HDPE blends when the blends are subjected to different processes.

Figure 6 is a table showing the properties of recycled HDPE that has been subjected to different processes.

Figure 7 is a broken away side elevational view of a prior art extruder.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, wherein the showings are for purposes of illustrating a preferred embodiment of the invention only and not for the purpose of limiting same, Figure 1 illustrates a pelletizing device 10 comprising a barrel 12, a screw
14 and a screw 15 (shown in Figure 2) mounted inside the barrel 12 so that they can be rotated by a drive (not shown). Screws 14 and 15 are identical, and only screw 14 will be described hereafter. Pelletizing device 10 includes a first end 16 and a second end 18 and a die 20 having at least one opening 22 mounted at second end 18. Barrel 12 has a circular cross section and a circular inner passage 24 extending from first end 16 to second end 18, an input opening 26 providing access to inner passage 24 and a vent 28 that allows the release of volatiles or other gasses generated during the processing of materials.

Screw 14 is rotatable about a longitudinal axis 30 and comprises a plurality of first segments 32 and second segments 34. Each of the first and second segments 32, 34 has two separate flights. The first segments 32 are assembled end to end to form a first portion of a screw and the second segments 34 are assembled end to end to form a second portion of a screw. When the first and second portions are connected, the resulting screw 14 has a first flight 36 and a second flight 38 running the length thereof. First segments 32 have a first length, about 37.5 mm in the preferred embodiment, while second segments 34 preferably have a shorter length, about 25 mm in the preferred embodiment. Each flight 36, 38 on each of the first segments 32 and the second segments 34 extends one revolution around the segment 32 or 34, and thus the segments 32, 34 can be joined end to end. The flights 36, 38 on each segment can be aligned with the flights on adjacent segments to form two continuous flights along the length of the screw 14 despite the different lengths of the first segments 32 and the second segments 34.

The screw 14 includes a first portion 40 formed of a plurality of the first segments 32 and a second portion 42 formed of a plurality of the second segments 34. The pitch of the first flight 36 along the first portion 38 is 37.5 mm, and the pitch of the second flight 40 along the first portion 38 is also 37.5 mm; the first and second flights 36, 38 are separated by about half the length of a first segment 32 or by about 19 mm. The pitch of the first flight 36 along the second portion 42 is 25 mm, as is the pitch of the second flight 38 along the second portion 42. The first portion 40 of the screw comprises about three-quarters of the length of the screw 14, the remaining one quarter of the screw’s length being formed by the second portion 42.

The pelletizing device 10 is divided into a plurality of zones, and the temperatures
of several of these zones can be independently controlled. Such control of multiple zones in an extruder is shown, for example, in U.S. 4,290,986, which patent is hereby incorporated by reference. Starting from first end 16 of the pelletizing device, these zones include a first zone 44, a second zone 46, a third zone 48, a fourth zone 50, a fifth zone 52 and a sixth zone 54. Associated with each of the zones 44, 46, 48, 50, 52 is an independently controllable heating element 56, preferably a resistance heating element, and a temperature sensor 58. Heating elements 56 and temperature sensors 58 are connected to a controller 60 that controls the temperature of the heating elements 56 and thus the temperature of the different zones 44, 46, 48, 50, 52.

In operation, powdered material is fed into pelletizing device 10 through opening 26 and is moved from first end 16 of the pelletizing device 10 toward second end 18 of pelletizing device 10 as screws 14, 15 rotate (in the counterclockwise and clockwise directions, respectively, as viewed in Figure 2). First zone 44 is either not heated or is maintained at a temperature significantly below the melting temperature of the material being processed. Second zone 46 is maintained at a temperature somewhat below the melting temperature of the material being processed, but at a sufficiently high temperature that the material softens -- this preheating of the material makes it easier to process in later zones. Third zone 48 is heated to approximately the melting temperature of the material being processed or to a temperature slightly higher than the melting temperature, to help ensure that the material begins to melt in third zone 48. The temperatures of fourth zone 50 and fifth zone 52 are either maintained at the same temperature as third zone 48 or at a slightly higher temperature, such as about 10 to 15 degrees F. higher, for example, to complete the melting process. However, the temperatures of all zones 44-52 are maintained below the level at which the chemical composition of the material would begin to change -- the compounding temperature -- to substantially prevent the degradation of the material as it is processed.

As the material moves toward fifth zone 52, it enters the second portion 42 of the pelletizing device 10 in which the pitches of the first flight 36 and second flight 38 decrease. This shorter pitch creates additional pressure in the material moving through the extruder that helps to provide a smooth extrusion of the now-melted material from the pelletizing device 10. After extrusion, the material is typically cooled in a water bath in a
well known manner and then cut into pellets by a rotating blade or similar mechanism 62 in a conventional manner.

Surprisingly, it has been found that by controlling the temperature of the various heating zones 44-52 of the pelletizing device 10 as described above, the powdered material input into the pelletizing device 10 can be melted and formed into pellets suitable for use in an injection molding machine without adversely affecting the properties of the powdered material. It was previously thought necessary to shear the powdered mixture as it passed through a pelletizing device in order to adequately melt and mix a powdered input and form it into pellets. Applicants have found, however, that this is not the case, and that by reducing or substantially eliminating shearing forces during the pelletization process, and controlling the temperature of a material as it is pelletized, a pellet suitable for further processing by an injection molding machine can be formed. The absence of kneading blocks or other elements that introduce a shearing force into the material while it is processed and the use of a fixed or constant diameter screw contribute to low levels of shear imparted to the powdered material as it is processed. It is believed that the shearing forces, in combination with the high compounding temperatures used in the prior art, were at least partially responsible for degrading the properties of the materials formed by such prior art processes.

The effects of processing powdered materials directly and of processing materials formed by a standard pelletization process and by the low-shear pelletization process of the subject invention will be better appreciated from an examination of the tables in Figures 3-6 which are discussed below.

Figure 3 illustrates the properties of extruded materials formed from one of three different inputs: a powder, a pelletized material formed by a standard pelletization process, and a pelletized material formed by the above-described low-shear pelletization process. As shown in Figure 3, the input material was either a 90/10 or 70/30 mixture of two virgin LLDPE materials, XU6158.20 and Dowlex 2500, respectively. The pull rate used was 2 inches per minute, and the melt flow rate (MFR) conditions were 190 C/2.16 kg. When processing LLDPE, it was found that a screw rotation rate of about 400 RPM, and temperatures of 300°F, 310°F, 310°F, 310°F and 315°F in zones 46, 48, 50, 52 and 54 provided satisfactory results. These temperatures are significantly
lower than convention compounding temperatures, 150° to 200° lower, for example.

As can be seen from this table, pelletizing the 90/10 virgin LLDPE blends using the low shear pelletization process produces a material that has a higher ultimate tensile strength than materials formed by a standard pelletization processes. The benefits of the low shear process in connection with the 70/30 blend are even more pronounced. Here, the percentage of elongation of the low shear processed materials is greater than the percentage of elongation of the materials processed using standard pelletization processes, while the melt flow rate (MFR) is maintained.

Figure 4 is a table showing the properties of an extruded material formed from one of three different inputs: a powder, a pelletized material formed by a standard pelletization process and a pelletized material formed by the above-described low-shear pelletization process. The material used as input was a blend of HDPE, LDPE, PP, PS and PVC in the ratio of 15/68/13/2/2. The pull rate used was 2 inches per minute, and the melt flow rate (MFR) conditions were 190 C/2.16 kg. When processing this blend, it was found that a screw rotation rate of about 400 RPM, and temperatures of 200°F, 300°F, 300°F, 320°F and 325°F in zones 46, 48, 50, 52 and 54 provided satisfactory results.

One significant advantage of the low shear process is that the material formed by the low shear pelletization process exhibits yield stress while the material formed by standard pelletization does not. Moreover, the material processed by low shear pelletization has a higher ultimate tensile strength and an Izod impact strength that is over 3 foot pounds per inch greater than the Izod impact strength of the material formed by standard pelletization, while substantially maintaining the MFR of the original powder. As those skilled in the art will appreciate, increasing notch impact strength significantly without adversely affecting other properties of a material is not a easy task. However, this is exactly what is accomplished by the method of the present invention. While this table shows that materials processed by a standard pelletization process have a high MFR, it is believed that this MFR is elevated because of the partial breakdown of the PVC component of the blend during processing.

Figure 5 is a table showing the properties of extruded materials formed from one of three different inputs: a powder, a pelletized material formed by a standard pelletization process and a pelletized material formed by the above-described low-shear
pelletization process. As shown in the table, the mixture was either a 90/10 or 75/25 mixture of two virgin HDPE materials, M6210 and XH6012, respectively. The pull rate used was 2 inches per minute, and the melt flow rate (MFR) conditions were 190 C/2.16 kg. When processing this blend, it was found that a screw rotation rate of about 300 RPM, and temperatures of 360°F, 375°F, 385°F, 385°F, 385°F in zones 46, 48, 50, 52 and 54 provided satisfactory results.

As can be seen from Figure 5, for the 90/10 blend, the percentage of elongation and the ultimate tensile strength of the material processed by the low shear pelletization process are significantly higher than the material processed by the standard process, while the MFR is substantially maintained. With respect to the 75/25 blend, the ultimate tensile strength is higher and the Izod impact strength is significantly higher than when the standard pelletization process is used.

Figure 6 is a table showing the properties of an extruded material formed from one of three different inputs: a powder, a pelletized material formed by a standard pelletization process and a pelletized material formed by the above-described low-shear pelletization process. The material used was taken from a batch of recycled mixed-color plastics. The pull rate used was 2 inches per minute, and the melt flow rate (MFR) conditions were 190 C/2.16 kg.

As will be appreciated from Table 6, the material processed by the low-shear pelletization process maintained its elongation and did so with less variance than occurred when the material was processed by standard pelletization techniques. The melt flow rate of the material formed by the low-shear pelletization process was also similar to the melt flow rate of the powder. The rate was substantially better than the MFR of pellets that had been formed by a standard pelletization process, showing that the standard pelletization process had changed the molecular weight of the material during processing.

The foregoing invention has been described in terms of a preferred embodiment; however, it should be understood that numerous obvious changes and additions to the invention will become apparent to those skilled in the relevant arts upon a reading of the foregoing description. For example, while twin screws are used in the above-described device, a single screw could be used without departing from the teaching of this
disclosure. It is intended that all such modifications and additions comprise a part of the subject invention to the extent they come within the scope of the several claims appended hereto.
We claim:

1. A method of pelletizing material comprising the steps of:
   placing a material to be pelletized into an extruder having at least one screw, a
   discharge end, and a die having at least one opening at the discharge end;
   actuating the at least one screw to move the material toward the discharge end and
   through the at least one opening in the die;
   heating the material as it travels toward the discharge end to at least partially melt
   the material while preventing the temperature of the material from reaching a
   compounding temperature; and
   cutting the material into pellets after it passes through the at least one opening in
   the die.

2. The method of claim 1, wherein said step of heating the material as it travels
   toward the discharge end comprises the steps of heating the material to a first temperature
   along a first portion of the extruder and heating the material to a second temperature
   along a second portion of the extruder.

3. The method of claim 2, wherein the second temperature is greater than the first
   temperature.

4. The method of claim 1, wherein said step of heating the material as it travels
   toward the discharge end comprises the steps of heating the material to a first temperature
   along a first portion of the extruder, heating the material to a second temperature along a
   second portion of the extruder and heating the material to a third temperature along a
   third portion of the extruder.

5. The method of claim 4, wherein the third temperature is greater than the
   second temperature and the second temperature is greater than the first temperature.

6. The method of claim 1, wherein said step of actuating the at least one screw
   comprises the step of rotating the at least one screw.
7. A method of pelletizing material having physical properties and a chemical composition, comprising the steps of:
   applying sufficient energy to the material to change a physical property of the material without changing the chemical composition of the material;
   extruding the physically changed material; and
   forming the extruded physically changed material into pellets.

8. The method of claim 7, wherein said step of forming the extruded material into pellets comprises the step of cutting the extruded material.

9. The method of claim 7, wherein said step of applying sufficient energy to the material to change a physical property of the material comprises the step of applying sufficient heat to the material to at least partially melt the material.

10. The method of claim 7, wherein said step of applying sufficient heat to the material to change a physical property of the material comprises the step of applying sufficient heat to the material to melt the material.

11. A method of pelletizing material comprising the steps of:
   providing an extruder having a screw having at least one flight and no kneading blocks, a discharge end, and a die having at least one opening at the discharge end;
   heating the extruder;
   placing the material into the extruder;
   rotating the screw to move the material toward the discharge end and through the at least one opening in the die; and
   cutting the extruded material into pellets.

12. The method of claim 11, including the additional step of controlling a temperature of the material as it travels toward the discharge end to at least partially melt the material.
13. The method of claim 12, including the additional step of preventing the temperature of the material in the extruder from reaching a compounding temperature of the material.

14. Pelletized material produced by a method comprising the steps of:
adding a substance comprising a compatibilized mixture of at least two non-compatible polymers formed by solid state shear pulverization to an extruder having a screw, a discharge end, and a die having at least one opening at the discharge end;
actuating the screw to move the substance toward the discharge end and through the at least one opening in the die;
controlling a temperature of the substance as it travels toward the discharge end to at least partially melt the substance while preventing the temperature of the substance from reaching a compounding temperature; and

cutting the substance into pellets after it passes through the die.

15. The material of claim 14, wherein the substance includes LDPE.

16. The material of claim 14, wherein the substance includes LLDPE.

17. The material of claim 14, wherein the substance includes HDPE.

18. The material of claim 14, wherein the substance includes a polyolefin.

19. The material of claim 14, wherein the substance comprises a blend of polyolefins.

20. The material of claim 14, wherein said step of actuating the screw comprises the step of rotating the screw.

21. A pelletizer, comprising:
a barrel having a discharge end;
a screw having a constant diameter, at least one flight and no kneading blocks
mounted for rotation in the barrel;
a die having at least one opening at the discharge end; and
a cutter for cutting material exiting the die into pellets.

22. The pelletizer of claim 21, wherein said at least one flight comprises a first
flight and a second flight.

23. The pelletizer of claim 22, wherein said first flight and said second flight are
parallel.

24. The pelletizer of claim 21, wherein the at least one flight has a first pitch
along a first portion of the screw and a second pitch along a second portion of the screw.

25. The pelletizer of claim 24, wherein said second portion of the screw is
adjacent the discharge end and wherein said second pitch is less than said first pitch.

26. The pelletizer of claim 24, wherein said screw has a length, and said first
portion of said screw comprises about three quarters of said length.

27. The pelletizer of claim 25, wherein said screw has a length, and said first
portion of said screw comprises about three quarters of said length.

28. A method of pelleting material comprising the steps of:
providing an extruder having a screw with a constant diameter, at least one flight
and no elements adapted to impart a shearing force to the material in the extruder, a
discharge end, and a die having at least one opening at the discharge end;
placing the material into the extruder;
rotating the screw to move the material toward the discharge end and through the
at least one opening in the die; and
cutting the extruded material into pellets.

29. A method of processing a powdered material having a chemical composition comprising the steps of:

placing the powdered material into an extruder having a screw, a discharge end, and a die having at least one opening at the discharge end;

rotating the screw to move the powdered material toward the discharge end and through the at least one opening in the die; and

heating the powdered material as it travels toward the discharge end to at least partially melt the powdered material without changing the chemical composition of the material.

30. The method of claim 29, including the additional step of cutting the powdered material into pellets after it passes through the at least one opening in the die.

31. A method of pelletizing a blend of powdered solid state shear pulverized material comprising the steps of:

placing the powdered material into an extruder having a fixed-diameter screw, a discharge end, three zones and a die having at least one opening at the discharge end;

rotating the screw to move the material through the three zones toward the discharge end and through the at least one opening in the die;

independently controlling the temperature of the material in the zones; and

cutting the material into pellets after it passes through the at least one opening in the die.

32. The method of claim 31, wherein said step of rotating the screw comprises the step of rotating the screw at about 400 RPM.

33. The method of claim 31, wherein said step of independently controlling the temperature of the material in the zones comprises the steps of holding the temperature of a first one of the zones at about 200 degrees F., holding the temperature of a second one
of the zones at about 300 degrees F., and holding the temperature of a third one of the zones at about 320 degrees F.

34. The method of claim 33, wherein the second zone is closer to the discharge end that the first zone, and the third zone is closer to the discharge end than the second zone.

35. A method of pelletizing solid state shear pulverized linear low density polyethylene material comprising the steps of:

placing the powdered material into an extruder having a fixed-diameter screw, a discharge end, three zones and a die having at least one opening at the discharge end;
rotating the screw to move the material through the zones toward the discharge end and through the at least one opening in the die;

independently controlling the temperature of the material in the zones; and

cutting the material into pellets after it passes through the at least one opening in the die.

36. The method of claim 35, wherein said step of rotating the screw comprises the step of rotating the screw at about 400 RPM.

37. The method of claim 35, wherein said step of independently controlling the temperature of the material in the zones comprises the steps of holding the temperature of a first one of the zones at about 300 degrees F., holding the temperature of a second one of the zones at about 310 degrees F., and holding the temperature of a third one of the zones at about 315 degrees F.

38. The method of claim 37, wherein the second zone is closer to the discharge end that the first zone, and the third zone is closer to the discharge end than the second zone.

39. A method of pelletizing powdered solid state shear pulverized high density
polyethylene material, comprising the steps of:

placing the powdered material into an extruder having a fixed-diameter screw, a discharge end, three zones and a die having at least one opening at the discharge end;

rotating the screw to move the material through the zones toward the discharge end and through the at least one opening in the die;

independently controlling the temperature of the material in the zones; and

cutting the material into pellets after it passes through the at least one opening in the die.

40. The method of claim 39, wherein said step of rotating the screw comprises the step of rotating the screw at about 300 RPM.

41. The method of claim 39, wherein said step of independently controlling the temperature of the material in the zones comprises the steps of holding the temperature of a first one of the zones at about 360 degrees F., holding the temperature of a second one of the zones at about 375 degrees F., and holding the temperature of a third one of the zones at about 385 degrees F.

42. The method of claim 41, wherein the second zone is closer to the discharge end that the first zone, and the third zone is closer to the discharge end than the second zone.
Fig. 3  
EFFECT OF LOW SHEAR PELLETIZATION ON PHYSICAL PROPERTIES OF VIRGIN LLDPE BLENDS

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ULTIMATE (PSI)</th>
<th>STD DEV</th>
<th>% ELONG</th>
<th>STD DEV</th>
<th>MFR g/10min</th>
</tr>
</thead>
<tbody>
<tr>
<td>90/10 LLDPE (POWDER)</td>
<td>2425</td>
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<td>393</td>
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Fig. 4
EFFECT OF LOW SHEAR PELLETIZATION ON PHYSICAL PROPERTIES OF RECYCLED FIVE COMPONENT BLEND

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### Fig. 5
EFFECT OF LOW SHEAR PELLETIZATION ON PHYSICAL PROPERTIES OF VERGIN HDPE BLENDS

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Fig. 6
EFFECT OF LOW SHEAR PELLETIZING ON PHYSICAL PROPERTIES OF RECYCLED HDPE

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### INTERNATIONAL SEARCH REPORT

**A. CLASSIFICATION OF SUBJECT MATTER**

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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)

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

Electronic database consulted during the international search (name of database and, where practical, search terms used)

EPO-Internal, PAJ

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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Further documents are listed in the continuation of box C.

**D. PATENT FAMILY MEMBERS**

Patent family members are listed in annex.

**E. SPECIAL CATEGORIES OF CITED DOCUMENTS**

- **X** document defining the general state of the art which is not considered to be of particular relevance
- **E** earlier document but published on or after the international filing date
- **L** document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- **O** document referring to an oral disclosure, use, exhibition or other means
- **P** document published prior to the international filing date but later than the priority date claimed

**F. DATE OF ACTUAL COMPLETION OF THE INTERNATIONAL SEARCH**

4 March 2004

Authorized officer

Kofood, J
## INTERNATIONAL SEARCH REPORT

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