

METHOD FOR RECYCLING POLYETHYLENE TEREPHTHALATE

FIELD OF THE INVENTION

[001] The present invention relates to a method for recycling polyethylene terephthalate (PET), in particular, to a method for the recycling of PET water jugs, and in particular but not exclusively to 5-gallon (19 litre) PET water jugs to enable the recycled PET to be subsequently reformed back into PET water jugs or back into PET water bottles by the manufacturer or by a third party.

BACKGROUND OF THE INVENTION

[002] Man-made plastics materials are ubiquitous and the non-biodegradable forms have led to a global crisis in waste management, as improper disposal of plastics products has caused significant environmental damage. One such non-biodegradable man-made plastics material is the polymer, polyethylene terephthalate (PET).

[003] PET is a thermoplastic material widely used in various industries on account of its light weight, transparent properties, its chemical resistance, and thermal stability, as well as its gas barrier properties. In fact, PET bottles make up the second largest category of plastics packaging used today, and their production is predicted to grow further.

[004] However, the ever-increasing use of PET products together with their prevalence as a single-use product has meant that it is now a major source of accumulated waste in landfills. The irony is that PET is recyclable and recycling PET is crucial in mitigating this landfill crisis, as it can significantly reduce the amount of plastics waste that ends up in landfills or in the oceans. To address this issue, recycling methods have been developed over the years and have evolved into several types.

[005] In general, for PET, there are three types of recycling methods in use today and they are mechanical recycling involving the shredding (also known as the granulating) of PET waste into smaller pieces, followed by cleaning, melting, and molding; chemical recycling like glycolysis and methanolysis which produce high-quality PET monomers; and biological recycling which uses enzymes or microorganisms to degrade PET waste into simpler

compounds. Mechanical recycling is the most common method and is a cost-effective and energy-efficient method able to reduce greenhouse gas emissions and conserve natural resources.

[006] However, mechanical recycling is not straight forward on account of the changing nature of the PET once it has been formed into a product. For example, virgin PET resin used to manufacture refillable 5-gallon (19 litre) water jugs, typically has an intrinsic viscosity (IV) of around 0.84. (any type of PET water jug be they for example, 3-gallon (11 litre), 4-gallon (15 litre) or 5-gallon (19 litre), will be referred to as a jug or PET water jug hereafter). After its conversion into such jugs (e.g., injection-stretch blow molding), tests show a drastic IV drop to as low as ~ 0.70 . More importantly the IV is not uniform within a jug, as certain regions measure ~ 0.70 , while others measure ~ 0.75 , and still others measure up to ~ 0.80 (e.g., near the neck). This heterogeneous intra-article variability complicates the recycling of PET back to food-grade recyclable PET, because downstream flake and pellet populations inherit and can even amplify these IV gradients.

[007] Additionally, compared to their thinner-walled PET bottle counterparts, the thicker walled jugs, once granulated into flakes during the early stages of the recycling process, often contain internal moisture, not usually found in their thinner-walled PET bottle flake counterparts, on account of their thicker walls. This increased internal moisture is not detectable through conventional surface moisture testing, and if this internal moisture is not eliminated prior to the formation of PET pellets during the extrusion step of the recycling process, it can result in an abnormally high intrinsic viscosity (IV) drop, often exceeding 0.10.

[008] Therefore, the technical challenge in any mechanical PET recycling process is twofold: (i) restore the IV to food-grade targets (~ 0.84 for jug-to-jug recycling applications and ~ 0.80 for jug-to-bottle recycling applications) and (ii) deliver a homogeneous material with lot-to-lot $\Delta IV \leq 0.02$ max, in other words, a homogenous material with a very tight IV uniformity. Not to do so, would run the risk of causing melt instability due to the high IV variance, being off-spec, and to 'mechanicals' issues. In addition, there would also be colour drift and throughput penalties.

[009] Usually, to restore/increase the IV of PET pellets at this stage during the recycling process, one typically extends the solid state polycondensation (SSP) residence time, as the increased time that polymer pellets spend under specific temperature/vacuum/gas flow conditions, the greater their degree of polymerization and improvement in their IV level. The downside to increasing the residency time, will however, decrease the line throughput and thus increase the processing costs.

[0010] In addition, such jugs come in two varieties so-called old-style (or legacy) jugs and new-style (or modern) jugs, the former possessing difficult to remove labelling while the latter have 'Easy Peel Off' labelling. The removal of both these types of labelling has also produced issues for the recycling process on account of their respective ease/difficulty of removal.

[0011] Other processing adjustments that have also been looked into to achieve an elevated and equalized IV have involved tuning the broader process, feedstock preparation and blending, pre-drying/moisture control, extrusion settings (temperature profile, screw speed, vacuum, filtration), pellet crystallinity and size, SSP temperature and gas flow, together with the tightening of quality control (QC).

[0012] Conventional PET bottle recycling lines tend to be optimized for single-use bottles and their labels. Refillable jugs, because they tend to use heavy-duty labels/adhesives and exhibit significant intrinsic viscosity (IV) loss and variation as well as possessing a higher bulk density, make them unsuitable for these conventional recycling lines, making standard processes unsuitable for food-grade jug circularity. Accordingly, existing mechanical PET recycling systems lack jug-specific recycling capabilities at scale.

[0013] It is therefore an object of the present invention to try to address the aforesaid technical challenges by *inter alia* modifying an existing PET bottle recycling line to accommodate and deal with thicker walled jugs.

SUMMARY OF INVENTION

[0014] With the foregoing in view, the invention, although embodied in several different aspects, is so linked as to form part of a single general inventive concept.

[0015] Accordingly, the invention in one aspect resides broadly in a method for recycling PET comprising the following steps, being provided with a plurality of PET water jugs, manually delabelling the jugs, granulating the jugs to form pieces of PET material, washing the pieces of PET material to remove any remaining pieces of labelling and/or the label attaching glue from the jugs, sieving the pieces of PET material to remove PET material fines to leave sorted PET material, homogenizing the sorted pieces of PET material to reduce the variance in their intrinsic viscosity (IV), drying the sorted pieces of PET material in a drying chamber wherein the drying chamber is capped at a fill percentage in the range of 50-60%, removing the resulting PET material and performing an IV check on the resulting PET material and removing those pieces of PET material that fall outside the limits of food-grade PET and subjecting the resulting PET material to solid state polycondensation (SSP) to increase its IV.

In another aspect of the present invention, the invention resides broadly in a method for recycling PET comprising the following steps, being provided with a plurality of legacy and modern PET water jugs, granulating the jugs to form pieces of PET material, washing these granulated pieces of material to remove any remaining pieces of labelling and/or the label attaching glue from the jugs, sieving the pieces of PET material to remove PET material fines to leave sorted PET material, homogenizing the sorted pieces of PET material to reduce the variance in their intrinsic viscosity (IV), drying the sorted pieces of PET material in a drying chamber wherein the drying chamber is capped at a fill percentage in the range of 50-60%, removing the resulting PET material and performing an IV check on the resulting PET material and removing those pieces of PET material that fall outside the limits of food-grade PET, and subjecting the resulting PET material to solid state polycondensation (SSP) to increase its IV.

[0016] In yet another aspect of the present invention, the invention resides broadly in apparatus for recycling PET comprising granulator apparatus to convert PET water jugs into granulated pieces of PET material, a washing line adapted to wash the PET material and remove any remaining pieces of labelling and/or the label attaching glue from the pieces of PET material, at least one sieve to sieve and remove granulated pieces of PET material fines to leave sorted pieces of PET material, at least one homogenizer adapted to homogenize the sorted pieces of PET material to reduce the variance in their intrinsic viscosity (IV), a drying

chamber provided with a level sensor configured to ensure that the fill percentage of batches of homogenized sorted pieces of PET material when present within the drying chamber, is in the range of 50-60% of the drying chamber's working volume, an extruder adapted to extrude the dried PET material, a pelletizer adapted to pelletize the extruded dried PET material, IV checking apparatus to perform an IV check on the pelletized PET material, and associated apparatus to remove removing those pieces of PET material that fall outside the limits of food-grade PET, and a solid state polycondensation (SSP) chamber adapted to increase the IV of the resulting food-grade PET material. Although manually stopping the filling of the drying chamber could be performed, in such form, a computer-controlled controller is used to stop the filling, once the drying chamber has reached its intended capacity.

[0017] In a final aspect of the present invention, the invention resides broadly in a system for recycling PET comprising granulator apparatus to convert PET water jugs into granulated pieces of PET material, a washing line adapted to wash the PET material and remove any remaining pieces of labelling and/or the label attaching glue from the pieces of PET material; at least one sieve to sieve and remove granulated pieces of PET material fines to leave sorted pieces of PET material, at least one homogenizer adapted to homogenize the sorted pieces of PET material to reduce the variance in their intrinsic viscosity (IV), a drying chamber provided with a level sensor configured to ensure that the fill percentage of batches of homogenized sorted pieces of PET material when present within the drying chamber, is in the range of 50-60% of the drying chamber's working volume, an extruder adapted to extrude the dried PET material, a pelletizer adapted to pelletize the extruded dried PET material, IV checking apparatus to perform an IV check on the pelletized PET material, and associated apparatus to remove removing those pieces of PET material that fall outside the limits of food-grade PET, and a solid state polycondensation (SSP) chamber adapted to increase the IV of the resulting food-grade PET material, the system converting PET items into food-grade pellets for the purposes of recycling back into PET items.

[0018] Each of the above methods, apparatus and system employ machines and a recycling line intended for PET bottle recycling, and as such, novel modifications to the line process have had to be made in order for the recycling to work, on account of the comparatively thicker wall of the jugs. With these modifications, each of the above methods (the first

dealing with easy to remove labels from modern jugs and the second dealing with hard to remove labels from legacy jugs and the third dealing with a mix of both modern and legacy jugs), the IV loss that occurs during the extrusion and pelletizing step, is largely reinstated, together with increased IV homogeneity, enabling the recycled PET to once again reach food-grade targets of ≈ 0.84 for jug-to-jug recycling applications and ≈ 0.80 for jug-to-bottle recycling applications. Accordingly, such results obtained by these methods will enable the subsequent recycling of (so-called 'end of life') original jugs, either back into jugs or back into thinner walled PET water bottles by either the recycler or by third parties.

[0019] Preferably, both the apparatus and the system are also provided with one or more of the following: a) PET delabelling apparatus; b) a further homogenizer; and c) optical sorting apparatus to sort pieces of PET material to enable the removal of non-desirable pieces of PET.

[0020] On account of the legacy jugs having harder to remove labels, compared to the modern jugs (due to a change in the adhesive used and/or the general technology used), the applicant intends to run the first two aspects of the present invention as specified hereinabove in tandem, with a gradual shift to the second aspect of the present invention as specified hereinabove. When all of the legacy jugs are no longer on the market, the intention is to revert back to the first aspect of the present invention.

[0021] Preferably, the PET water jugs are 5-gallon (19 litre) PET water jugs.

[0022] Preferably, the method for the first aspect of the invention further includes subjecting the sorted pieces of PET material to optical sorting to enable the removal of non-desirable pieces of PET. This is advantageous as the removal of non-desirable pieces of PET, i.e. those containing any labelling and/or the labelling attaching glue will lead to a purer recycled end product, and will also typically reduce the IV variance, (otherwise, a longer than normal residence time in SSP downstream in the method will be required to decontaminate the PET material and increase its IV, which is not desirable from an economical viewpoint). Although the optical sorting can be carried out by the human eye, when optical sorting takes place for any aspect of the invention, in such form, the optical sorting is carried out by High-Speed Laser Polymer Sorting or a Near Infra-Red recognition sensor. This reduces the overheads for the method as a human is no longer needed for this part of the method.

[0023] Preferably, the step of washing the delabelled granulated pieces in the first aspect of the present invention uses cold-water with no added chemicals. In such form, the cold washing will be in the form of high-friction washing with multi-stage rinsing.

[0024] Preferably, the step of washing the granulated pieces in the second aspect of the present invention involve hot washing the granulated pieces. In such form, the hot washing will be in the form of high-friction washing with multi-stage rinsing. Still further in such form, the hot washing is for 20 minutes at 95°C in a caustic soda (NaOH) concentration of 3% solution:detergent ratio of 1:4. These arrangements (in particular, the specific conditions of the hot wash set down above) maximise the efficiency of the cleaning/delabelling provided by the hot wash. This in turn, minimizes the glue/label carryover to the next stages.

[0025] In fact, internal reports carried out by the applicant have shown that employing these hot wash conditions, labelling on subsequent pieces has been reduced to 712 ppm, glue on the same is also down to 1,620 ppm, and the net label mass only ~4 ppm after the hot wash (washing yield ~98.05%).

[0026] When using the method, system or apparatus, preferably, the pieces of PET material that are initially created are in the form of flakes and the sorted dried PET flakes leave the drying chamber through an extruder and the extruded PET material is pelletized.

[0027] Homogenization can occur more than once. For example, the process of homogenization can occur twice when the PET is in the form of flakes, or the process of homogenization can occur more than once, when the PET is in the form of pellets, however, preferably, the process of homogenization occurs twice when the PET is in the form of flakes and once when the PET is in the form of pellets. In such form, the final IV variance is either $\sigma \leq 0.002$, or ≤ 0.0015). Thus, the apparatus and the system can possess at least one additional homogenizer.

[0028] Preferably, when the PET flakes are homogenized twice, they are homogenized in a first homogenizer, and then homogenized again in a different homogenizer. In such form, the second homogenizer is smaller than the first and also in such form, the second homogenizer is half the size of the first. Such an arrangement helps to produce a very tight IV variance.

[0029] Granulator screen sizes that are effective for the method apparatus or system of the present invention can range from those in the range of 20-22mm or larger, preferably, however, the step of granulating the jugs involves the use of granulator screens of in the range of 20-22mm. This particular size of granulator screen has the advantage of maximizing the amount of retainable granulated PET (as fines are removed) and also tends to ensure that the target bulk density value for the PET flakes of 400kg/m^3 is more or less achieved.

[0030] If this level of bulk density is exceeded, it may damage the PET bottle recycling line. In such form, the granulating step when using the method, apparatus or system only occurs once. This keeps the amount of discardable fines to a minimum (as undergoing more than one granulating step will generate an undesirable second round of finer 'fine' portions that will also need to be discarded) as any increase from this minimum will raise the bulk density beyond the target value of 400kg/m^3 , which will undermine the drying chamber's stability and lead to over-torquing and thus possible damage to the drying chamber.

[0031] In addition, by using a 22mm (entry) / 20mm (exit) grate in the applicant's granulator, not only is a just a small proportion of flakes above 14mm (approximately 1–2%) obtained (which helps decrease the overall bulk density to around 400kg/m^3), but there is also an increase in the average flake size overall, the majority of flakes end up around 6mm and larger, rather than having a significant share below 6mm and 4mm - which, since they must be rejected, would negatively affect the economics.

[0032] Preferably, the PET fines that are discarded are defined as those that are less than 4mm in size. The advantage of discarding the fines of less than 4mm is that it enables the optical sorter's ejection efficiency in the subsequent step to increase, as larger sized pieces (4mm and greater) are easier to optically sort. It also decreases the bulk density further helping it to get closer to the desired value of 400kg/m^3 .

[0033] In addition, whether using the method, system or apparatus, preferably a portion of those PET flakes that are greater than 14mm in size is also kept. In such form retaining a portion of the PET pieces that are greater than 14mm, enables the bulk density of the sorted PET material to be lowered as it moves to the drying chamber. It also helps to stabilise the torque of the drying chamber. In other words, the sorted PET material is in the range of 4-

14mm, together with a proportion of granulated PET that is larger than 14mm to ensure that the target bulk density of 400kg/m³ of the PET material is reached.

[0034] Preferably, the drying chamber used to dry the sorted PET material in the method, apparatus or the system is a combined drying unit (CDU) which is capped at a fill percentage in the range of 50-60%. In such form the fill percentage is capped at 55%. Any more than this and the mechanical load on the drying vessel's agitator (as the CDU is intended for PET bottle recycling) will rise sharply and this may again lead to over-torquing and thus damage to the CDU. Furthermore, in such form, the drying chamber possesses a slower agitation than normal to reduce torque spikes and extend motor/gear life.

[0035] Preferably the operating temperature range of the CDU is in the range of 160-170°C. which might be accompanied with an associated hot air flow. In such form, the operating temperature of the CDU is 165°C.

[0036] As the flakes from jugs are typically thicker than conventional PET containers such as PET bottle flakes, their melt time will be longer and they will also have a tendency to retain "hidden" internal moisture. Accordingly, preferably, the sorted flakes are dried to remove both surface and internal moisture. This thorough form of drying stabilizes both the extrusion process and limits what would otherwise be a dramatic fall in the IV, as in-house tests have indicated that thicker PET flakes and retained internal moisture contributes to dramatic falls in IV during extrusion.

[0037] Preferably, the fill percentage of the CDU is determined by one or more level sensors fitted to the CDU. In such form, a computer-controlled controller is used to stop the filling, once the drying chamber has reached its intended capacity.

[0038] Preferably, upon extrusion from the CDU, the extruded material is pelletized and these PET pellets undergo an in-line, real-time IV check and those PET pellets that fall outside a predetermined target band for the intended article that they are going to become are removed, so as to maintain convergence to an end-of-line lot IV spread ($\Delta IV \leq \pm 0.02$ max).

[0039] Preferably, the temperature profile and screw speed of the extruder used to extrude the material from the CDU is monitored constantly in real time to try and maintain the IV profile of the PET pellets.

[0040] Those PET pellets that meet the requirements, pass on into the SSP. Preferably, the residence time of the food grade PET pellets in the SSP is in the range of 6 to 10 hours. In such form, the residence time is ideally 8 hours. This helps to ensure that the throughput of the line remains unchanged and does not negatively affect the economics of the method.

[0041] Preferably, the operating temperature of the SSP is in the range of 150-250°C. In such form, the operating temperature is ideally 200°C. (the SSP Preheater being at 210°C and the SSP Reactor at 200°C).

[0042] Preferably, quality control checks are carried out on each batch of food grade PET pellets from the SSP. This ensures only the best batches are sent on for recycling back into jugs or PET bottles.

[0043] Although jugs supplied from multiple suppliers could be used in the method of the present invention, preferably, the jugs are sourced from a single manufacturer. Known as a single stream jug workflow, only taking jugs from a single manufacturer has the advantage of stabilising the colour/clarity and quality of the jugs thus providing a uniform feedstock which tends to lead to a more uniform recycled product.

[0044] The invention also includes within its scope a recycled PET pellet formed by the method according to any one of the preceding claims, ready for recycling into either a PET water jug or a PET water bottle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045] To facilitate an understanding of the invention, there is illustrated in the accompanying sheets of drawings the preferred embodiments from an inspection of which when considered in connection with the following description, the invention, its construction and operation and many of its advantages would be readily understood and appreciated.

[0046] **FIG. 1** illustrates a flow chart of the method for recycling PET that is the subject of the present invention.

[0047] **FIG. 2** illustrates a front view of an empty polyethylene terephthalate (PET) 5-gallon (19 litre) water jug.

[0048] **FIG. 3** illustrates a series of views of a 'rotary wheel' apparatus currently used by the applicant to manually delabel old-style 5-gallon (19 litre) jugs, the other images in this series showing workers either collecting jugs or operating the apparatus to manually delabel a jug.

[0049] **FIG. 4** illustrates the in-line sequence of events of the method of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0050] With reference to **Figs 1, 2, 3 and 4**, these show respectively, the preferred way of carrying out the recycling process (Fig 1) of the present invention, using the apparatus (of Figs 3 when required, and 4) together with an image of what is being recycled (Fig 2), a 5-gallon (19 litre) polyethylene terephthalate (PET) water jug (known hereafter as a jug, or if there is more than one, jugs).

[0051] Empty old jugs that cannot be re-used are supplied to the applicant's recycling plant for recycling from a single supplier, where (if required) they are first sorted into old-style (or legacy) jugs or new-style (or modern) jugs for recycling, the former possessing difficult to remove labelling while the latter have 'Easy Peel Off' labelling. Any non-PET components that may come with the jugs (legacy or modern) are also removed and discarded during this initial sorting stage.

[0052] The legacy jugs containing the difficult to remove labelling (on account of a different adhesive being used) compared to the modern jugs, are currently manually delabelled, using a 'rotary wheel' delabelling apparatus of the type shown in **Fig 3** to reduce contamination prior to granulating and then the resulting granulated pieces in the form of PET flakes are

just cold washed in water employing high-friction washing with multi-stage rinsing to remove any remaining pieces of labelling and/or the label attaching glue from the granulated pieces.

[0053] The modern jugs do not require the use of the ‘rotary wheel’ delabelling apparatus currently used for the legacy jugs, because a different adhesive is used, and as a result, these jugs are instead, granulated and delabelled by simply hot washing the PET flakes for 20 minutes at 95°C in a caustic soda (NaOH) concentration of 3% solution:detergent ratio of 1:4 to remove the labelling and/or the labelling attaching glue from the PET flakes.

[0054] Recently in-house testing has shown that both the legacy and modern jugs may be granulated together, (without any prior sorting) and if the granulated PET flakes are subjected to the same hot washing conditions as described in the previous paragraph, not only are the modern PET flakes cleaned but much of the legacy PET flakes are cleaned as well, and any PET Flakes (modern and legacy) that still retain pieces of labelling and/or the label attaching glue may simply be removed during the optical scanning step (see later).

[0055] Accordingly, although the first method is currently being used in-house by the applicant, there is now a gradual shift towards the above method of granulating non-separated jugs to produce PET flakes and hot washing them, (despite a lower overall yield on account of rejection by the optical sorter – see later) thus both methods are to varying degrees currently being used. Inevitably, once the legacy jugs cease to exist, only the first method described above will be used. This will ultimately negate the need for any initial sorting step, if one is even required.

[0056] The size reduction or granulation step is performed once only, using granulator screens with a 22mm (entry)/20mm (exit) in the applicant’s granulator to form granulated PET flakes.

[0057] The PET flakes are then sieved to remove PET fines of less than 4mm which are discarded, and a portion of the PET flakes which are greater than 14mm in size are kept to leave sorted PET flakes. This is followed by passing the sorted flakes through a High-Speed Laser Polymer Sorting or a Near Infra-Red optical recognition sensor to eject non-conforming flakes (e.g., residual attached glue/labels, and non-PET items).

[0058] The sorted PET flakes (now considered to be a true work batch) are then blended in a first homogenization silo to reduce the variance in the flakes intrinsic viscosity (IV) inherent to these jugs. The changes in IV (ΔIV) may be up to ~ 0.10 depending on the cuts/zones of the flakes, as the IV of jug neck flakes are different to the IV of jug body flakes which are also different to jug base flakes. This first homogenization mix evens the feed before the drying and extrusion steps.

[0059] The homogenized work batch is then transferred from this first homogenization silo to a second homogenization silo which is approximately half the size of the first, where it undergoes a further blending or homogenization to further compress the IV variation ahead of the thermal processing step of the method.

[0060] After the second homogenization step, the work batch is fed into a commercially available central drying unit (CDU). As the CDU is normally used to dry thinner-walled PET bottle flakes, it has had to be modified to deal with the thicker flakes from jugs). Accordingly, the CDU has been equipped with a level sensor which is operatively connected to a computer-controlled controller so programmed as to stop the filling, once the drying chamber has reached its intended capacity, in order to keep the work batch bed level at or below 55% of the CDU working volume. Limiting the fill in this manner protects the agitator/drive of the CDU from over torque/overload caused by the higher bulk density/weight of jug flakes relative to bottle flakes. In addition, the CDU is so arranged as to have variable frequency drive ramping (VFD) and the VFD ramps are tuned to ensure slower agitation than normal (for PET bottles) to reduce torque spikes which will also extend the motor/gear life associated with the CDU. The work batch is then dried in the CDU, to remove both surface and internal moisture, the latter requiring a longer residence time in the CDU than is customary for the thinner walled PET bottle flakes.

[0061] The dried work batch is then fed into an extruder and extruded from the CDU where it is converted into PET pellets. These PET pellets then undergo an in-line, real-time IV check, and those PET pellets that fall outside a predetermined target band for food-grade PET are removed so as to maintain convergence to an end-of-line lot IV spread ($\Delta IV \leq \pm 0.02$). The temperature profile and screw speed of the extruder is monitored constantly in real time to try and maintain the IV profile of the PET pellets.

[0062] The food grade PET pellets are now subjected to solid state polycondensation (SSP) to increase/restore the IV of the PET pellets. Specifically, the residence time of the food grade PET pellets in the SSP is set at 8 hours, and the operating temperature of the SSP is 200°C. This arrangement raises the IV to be approximately 0.85 which is ideal for the subsequent recycling of the food grade pellets into jugs. In alternative embodiments, conditions are set at this stage to enable the IV to tend towards that required for the recycling of the PET bottles. Such conditions for example require a lower temperature to reach the ideal 0.80 IV for the eventual recycling of the PET pellets into PET bottles by a third party.

[0063] The SSP is continuously fed, but its contents are discharged in batches of food grade PET pellets, (the lower layers having had a longer residence time than the upper ones). Accordingly, when a batch is discharged, if the IV falls outside the predefined target range, it will be diverted to a non-food grade homogenising silo, rather than a food grade homogenizing silo.

[0064] Such an arrangement ensures that when the food grade PET pellets are discharged, the discharged batches already possess an increased IV, and narrower ΔIV to begin with, prior to undergoing their final homogenization to narrow down the IV variance once again. The narrowing is extremely efficient, leading to an even narrower final ΔIV . Typically, the IV tolerance of such a batch of pellets for the subsequent recycling back into jugs after this final homogenization by a third party, is 0.85 ± 0.02 max, or 0.80 ± 0.02 max for the subsequent recycling back into PET bottles across the entire batch.

[0065] The final stage of the method using the apparatus shown, involves standard quality control checks, such as checking on the colour or the IV of the batch to make sure it passes muster. At this point the batch is now fully recycled awaiting to be shipped out for blow-molding back into jugs.

[0066] It should be further appreciated by a person skilled in the art that variations and combinations of features described above, not being alternatives or substitutes, may be combined to form yet further embodiments falling within the intended scope of the invention.

CLAIMS

1. A method for recycling PET comprising the following steps:

being provided with a plurality of PET water jugs;
manually delabelling the jugs;
granulating the jugs to form granulated pieces of PET material;
washing these granulated pieces of PET material to remove any remaining pieces of labelling and/or the label attaching glue from the pieces;
sieving the granulated pieces of PET material to remove granulated pieces of PET material fines to leave sorted pieces of PET material;
homogenizing the sorted pieces of PET material to reduce the variance in their intrinsic viscosity (IV);
drying the sorted pieces of PET material in a drying chamber wherein the drying chamber is capped at a fill percentage in the range of 50-60%;
removing the resulting PET material and performing an IV check on the resulting PET material, and removing those pieces of PET material that fall outside the limits of food-grade PET; and
subjecting the resulting PET material to solid state polycondensation (SSP) to increase its IV.

2. A method for recycling PET comprising the following steps:

being provided with a plurality of legacy and modern PET water jugs,
granulating the jugs to form granulated pieces of PET material;
washing these granulated pieces of PET material to remove any remaining pieces of labelling and/or the label attaching glue from the jugs;
sieving the granulated pieces of PET material to remove granulated PET material fines to leave sorted pieces of PET material;
optically sorting the sorted pieces of PET material to enable the removal of non-desirable pieces of PET;
homogenizing the sorted pieces of PET material to reduce the variance in their intrinsic viscosity (IV);
drying the sorted pieces of PET material in a drying chamber wherein the drying chamber is capped at a fill percentage in the range of 50-60%;

removing the resulting PET material and performing an IV check on the resulting PET material, and removing those pieces of PET material that fall outside the limits of food-grade PET; and

subjecting the resulting PET material to solid state polycondensation (SSP) to increase its IV.

3. Apparatus for recycling PET comprising:

granulator apparatus to convert PET water jugs into granulated pieces of PET material;

a washing line adapted to wash the PET material and remove any remaining pieces of labelling and/or the label attaching glue from the pieces of PET material;

at least one sieve to sieve and remove granulated pieces of PET material fines to leave sorted pieces of PET material;

at least one homogenizer adapted to homogenize the sorted pieces of PET material to reduce the variance in their intrinsic viscosity (IV);

a drying chamber provided with a level sensor configured to ensure that the fill percentage of batches of homogenized sorted pieces of PET material when present within the drying chamber, is in the range of 50-60% of the drying chamber's working volume;

an extruder adapted to extrude the dried PET material;

a pelletizer adapted to pelletize the extruded dried PET material;

IV checking apparatus to perform an IV check on the pelletized PET material, and associated apparatus to remove removing those pieces of PET material that fall outside the limits of food-grade PET; and

a solid state polycondensation (SSP) chamber adapted to increase the IV of the resulting food-grade PET material.

4. Apparatus as claimed in claim 3, wherein the apparatus is also provided with one or more of the following:

a) PET delabelling apparatus;

b) a further homogenizer; and

c) optical sorting apparatus to sort pieces of PET material to enable the removal of non-desirable pieces of PET.

5. A system for recycling PET comprising:

granulator apparatus to convert PET water jugs into granulated pieces of PET material;

a washing line adapted to wash the PET material and remove any remaining pieces of labelling and/or the label attaching glue from the pieces of PET material;

at least one sieve to sieve and remove granulated pieces of PET material fines to leave sorted pieces of PET material;

at least one homogenizer adapted to homogenize the sorted pieces of PET material to reduce the variance in their intrinsic viscosity (IV);

a drying chamber provided with a level sensor configured to ensure that the fill percentage of batches of homogenized sorted pieces of PET material when present within the drying chamber, is in the range of 50-60% of the drying chamber's working volume;

an extruder adapted to extrude the dried PET material;

a pelletizer adapted to pelletize the extruded dried PET material;

IV checking apparatus to perform an IV check on the pelletized PET material, and associated apparatus to remove removing those pieces of PET material that fall outside the limits of food-grade PET; and

a solid state polycondensation (SSP) chamber adapted to increase the IV of the resulting food-grade PET material;

the system converting PET items into food-grade pellets for the purposes of recycling back into PET items.

6. The system of claim 5, wherein the system is also provided with one or more of the following:

a) PET delabelling apparatus;

b) a further homogenizer; and

c) optical sorting apparatus to sort pieces of PET material to enable the removal of non-desirable pieces of PET.

7. The method according to claim 1, wherein the method further includes the step of ensuring that the sorted pieces of PET material are the subject of optical sorting to enable the removal of non-desirable pieces of PET.

8. The method according to claim 2 or claim 7, the apparatus according to claim 4 and the system according to claim 6, wherein the optical sorting is carried out by a High-Speed Laser Polymer Sorting or a Near Infra-Red recognition sensor.

9. The method according to claim 1, or claim 2, wherein:

- a) the step of washing the delabelled granulated pieces uses cold-water with no added chemicals, and
- b) the washing step involves hot washing for 20 minutes at 95°C in a caustic soda (NaOH) concentration of 3% solution:detergent ratio of 1:4 when washing the granulated pieces the granulated pieces and employs high-friction washing with multi-stage rinsing.

10. The method according to any one of the preceding claims, wherein the pieces of PET material that are initially created are in the form of flakes, and the process of homogenization occurs twice when the PET is in the form of flakes, and once when the PET is in the form of pellets.

11. The method according to any one of the preceding method claims, wherein the step of granulating the jugs involves the use of granulator screens in the range of 20-22mm or the apparatus according claim 3 or claim 4, and the system according to claim 5 or claim 6, wherein the granulator employs screens in the range of 20-22mm, and granulation in the method, apparatus or system, when it occurs, only occurs once.

12. The method according to any one of the preceding method claims, the apparatus according claim 3 or claim 4, and the system according to claim 5 or claim 6, wherein the PET fines that are to be discarded are defined as those that are less than 4mm in size and a portion of the granulated PET that is greater than 14mm, is retained to lower the bulk density of the sorted PET material within the drying chamber.

13. The method according to any one of the preceding method claims, the apparatus according to claim 3 and the system according to claim 5, wherein the drying chamber used to dry the sorted PET material is a combined drying unit (CDU) and one or more of the following occurs:

- a) the fill percentage is capped at 55%;

- b) the operating temperature of the CDU is in the range of 160-170°C, and is preferably 165°C;
- c) the fill percentage is determined by one or more level sensors fitted to the CDU; and/or
- d) a computer-controlled controller is used to stop the filling, once the drying chamber has reached its intended capacity.

14. The method according to claim 13, wherein upon extrusion from the CDU, the extruded material is pelletised one or more of the following occurs:

- a) the pellets undergo an in-line, real-time IV check and those PET pellets that fall outside a predetermined target band for the intended article that they are going to become are removed so as to maintain convergence to an end-of-line lot IV spread ($\Delta IV \leq \pm 0.02$); and/or
- b) the temperature profile and screw speed of the extruder used to extrude the material from the CDU is monitored constantly in real time to try and maintain the IV profile of the PET pellets.

15. The method according to any one of the preceding claims, wherein the PET pellets are now subjected to solid state polycondensation (SSP) to increase/restore the IV of the PET pellets and to do so, one or more of the following occurs:

- a) the residence time of the dried pieces of PET material in the SSP is in the range of 6 to 10 hours, and is preferably 8 hours;
- b) the operating temperature of the SSP is in the range of 150-250°C, preferably 200°C.